Air Conditioning Clinic

Absorption Water Chillers

One of the Equipment Series

TRG-TRC011-EN

Absorption Water Chillers

One of the Equipment Series

A publication of
The Trane Company—
Worldwide Applied Systems Group

Preface

Absorption Water Chillers

A Trane Air Conditioning Clinic

Figure 1

The Trane Company believes that it is incumbent on manufacturers to serve the industry by regularly disseminating information gathered through laboratory research, testing programs, and field experience.

The Trane Air Conditioning Clinic series is one means of knowledge sharing. It is intended to acquaint a nontechnical audience with various fundamental aspects of heating, ventilating, and air conditioning. We have taken special care to make the clinic as uncommercial and straightforward as possible. Illustrations of Trane products only appear in cases where they help convey the message contained in the accompanying text.

This particular clinic introduces the concept of **absorption water chillers**.

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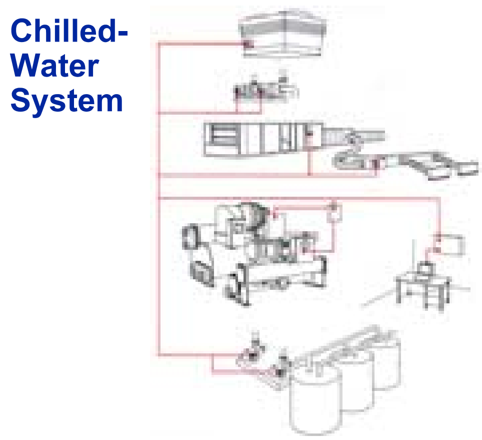

Figure 2

Water chillers are used in a variety of air conditioning and process cooling applications. They are used to make cold water that can be transported throughout a facility using pumps and pipes. This cold water can be passed through the tubes of coils to cool the air in an air conditioning application, or it can provide cooling for a manufacturing or industrial process.

Systems that employ water chillers are commonly called **chilled-water systems**.

Figure 3

Although water chillers come in many sizes and types, they all produce cooling using the same basic principles of heat transfer and change-of-phase of the refrigerant. This is accomplished by the chiller refrigeration cycle. They differ from each other based on the refrigeration cycle and the type of refrigerant fluid used.

TRANE

Introduction

notes

Water chillers using the vapor-compression refrigeration cycle vary by the type of compressor used. The compressor works to draw in refrigerant vapor and increase its pressure and temperature to create the cooling effect. Reciprocating, scroll, helical-rotary (or screw), or centrifugal compressors are generally used in water chillers that employ the vapor-compression refrigeration cycle.

Absorption water chillers make use of the absorption refrigeration cycle and do not use a mechanical compressor. The absorption refrigeration cycle is used in both small and large air-conditioning equipment. This clinic, however, focuses on large water-chiller applications of the absorption cycle. The different types of absorption water chillers will be discussed in detail in Period Two.

notes

Absorption Water Chillers

period one

Absorption Refrigeration Cycle

Figure 4

This period describes the components of the absorption refrigeration cycle. Comparing the absorption refrigeration cycle with the more familiar vapor-compression refrigeration cycle is often an easy way to introduce it. Like the vapor-compression refrigeration cycle, the absorption refrigeration cycle uses the principles of heat transfer and change-of-phase of the refrigerant to produce the refrigeration effect.

Both the vapor-compression and absorption refrigeration cycles accomplish cooling by absorbing heat from one fluid (chilled water) and transferring it to another fluid (cooling water or ambient air). Both cycles circulate refrigerant inside the chiller to transfer this heat from one fluid to the other. Both cycles also include a device to increase the pressure of the refrigerant and an expansion device to maintain the internal pressure difference, which is critical to the overall heat transfer process.

period one
Absorption Refrigeration Cycle

notes

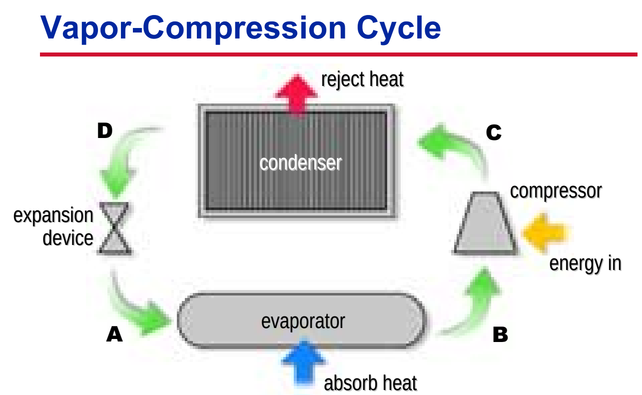

Figure 5

In the vapor-compression refrigeration cycle, refrigerant enters the evaporator in the form of a cool, low-pressure mixture of liquid and vapor (**A**). Heat is transferred from the relatively warm air or water to the refrigerant, causing the liquid refrigerant to boil. The resulting vapor (**B**) is then pumped from the evaporator by the compressor, which increases the pressure and temperature of the refrigerant vapor.

The hot, high-pressure refrigerant vapor (**C**) leaving the compressor enters the condenser where heat is transferred to ambient air or water at a lower temperature. Inside the condenser, the refrigerant vapor condenses into a liquid. This liquid refrigerant (**D**) then flows to the expansion device, which creates a pressure drop that reduces the pressure of the refrigerant to that of the evaporator. At this low pressure, a small portion of the refrigerant boils (or flashes), cooling the remaining liquid refrigerant to the desired evaporator temperature. The cool mixture of liquid and vapor refrigerant (**A**) travels to the evaporator to repeat the cycle.

The vapor-compression refrigeration cycle is discussed in detail in the *Refrigeration Cycle* clinic.

notes

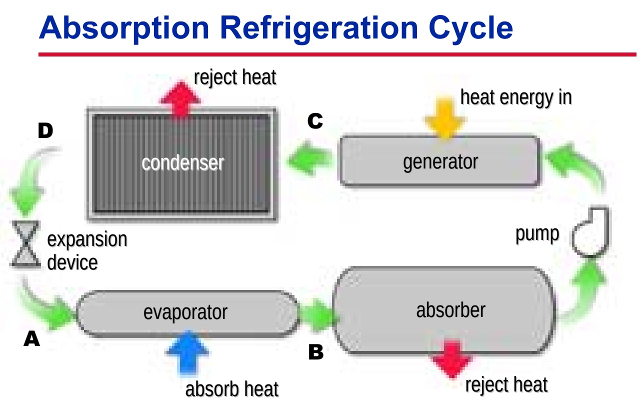

Figure 6

There are two fundamental differences between the absorption refrigeration cycle and the vapor-compression refrigeration cycle. The first is that the compressor is replaced by an absorber, pump, and generator. The second is that, in addition to the refrigerant, the absorption refrigeration cycle uses a secondary fluid, called the absorbent. The condenser, expansion device, and evaporator sections, however, are the same.

Refrigerant enters the evaporator in the form of a cool, low-pressure mixture of liquid and vapor (**A**). Heat is transferred from the relatively warm water to the refrigerant, causing the liquid refrigerant to boil. Using an analogy of the vapor-compression cycle, the absorber acts like the suction side of the compressor—it draws in the refrigerant vapor (**B**) to mix with the absorbent. The pump acts like the compression process itself—it pushes the mixture of refrigerant and absorbent up to the high-pressure side of the system. The generator acts like the discharge of the compressor—it delivers the refrigerant vapor (**C**) to the rest of the system.

The refrigerant vapor (**C**) leaving the generator enters the condenser, where heat is transferred to water at a lower temperature, causing the refrigerant vapor to condense into a liquid. This liquid refrigerant (**D**) then flows to the expansion device, which creates a pressure drop that reduces the pressure of the refrigerant to that of the evaporator. The resulting mixture of liquid and vapor refrigerant (**A**) travels to the evaporator to repeat the cycle.

The components of the absorption refrigeration cycle will be discussed in detail in a moment.

notes

Refrigerant

- **Distilled water**
  - Stable
  - Nontoxic
  - Low cost
  - Readily available
  - Environmentally friendly
  - High latent heat of vaporization

Figure 7

Absorption System Fluids

Probably the greater of these differences between the vapor-compression and absorption refrigeration cycles, however, is the types of fluids used. The vapor-compression refrigeration cycle generally uses a halocarbon (such as HCFC-123, HCFC-22, HFC-134a, etc.) as the refrigerant. The particular absorption refrigeration cycle discussed in this clinic uses distilled water as the **refrigerant**.

Distilled water is stable, nontoxic, low in cost, readily available, environmentally friendly, and has a relatively high heat of vaporization (1000 Btu/lb [2326 kJ/kg]). The heat of vaporization is the amount of heat required to fully transform (evaporate) liquid to a vapor at a given pressure. For the water to be used as a refrigerant, the cycle must operate in a vacuum, that is, at a pressure below atmospheric pressure. This will be discussed shortly. Finally, large quantities of water are easily absorbed by the absorbent and separated within the absorption cycle.

Throughout the remainder of this clinic, when the term refrigerant is used, it refers to distilled water.

notes

Absorbent

- **Lithium Bromide (LiBr)**
  - High affinity for water (refrigerant)
  - In solution, higher boiling point than water
  - Nontoxic

Figure 8

Additionally, the absorption refrigerant cycle uses a second fluid called an **absorbent** solution. The absorbent solution is confined to the absorber and generator sections of the cycle, and is used to carry the refrigerant from the low-pressure side (evaporator) to the high-pressure side (condenser) of the chiller. For this purpose, the absorbent should have a strong affinity (attraction) for the refrigerant and, when in solution with the refrigerant, a boiling point that is substantially higher than that of the refrigerant.

The absorbent commonly used with water (the refrigerant) is lithium bromide. Lithium bromide, a nontoxic salt, has a high affinity for water. Also, when in solution with water, the boiling point of lithium bromide is substantially higher than that of water. This makes it easy to separate the refrigerant from the absorbent at low pressures. A certain quantity of absorbent solution, therefore, is pumped from the absorber to the generator in order to transport the refrigerant.

Another common refrigerant–absorbent pair is ammonia as the refrigerant and water as the absorbent. These fluids are more common in small residential applications. There are other refrigerant–absorbent combinations; this clinic, however, will focus on water as the refrigerant and lithium bromide as the absorbent.

Absorption Refrigeration Cycle

notes

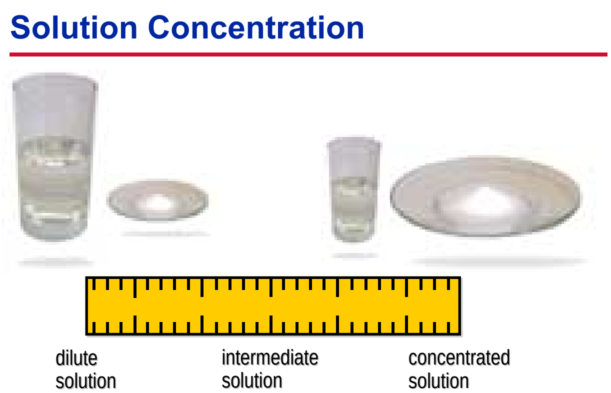

Figure 9

These two fluids, the refrigerant and the absorbent, are mixed inside the chiller in various concentrations. The term **dilute solution** refers to a mixture that has a relatively high refrigerant content and low absorbent content. A **concentrated solution** has a relatively low refrigerant content and high absorbent content. An **intermediate solution** is a mixture of dilute and concentrated solutions.

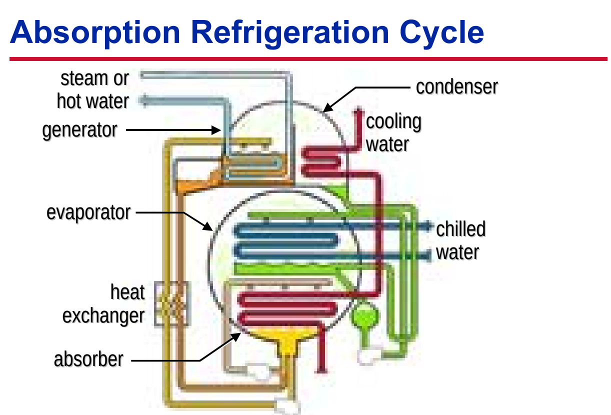

Figure 10

Components of the Absorption Cycle

The four basic components of the absorption refrigeration cycle are the generator and condenser on the high-pressure side, and the evaporator and absorber on the low-pressure side. The pressure on the high-pressure side of the system is approximately ten times greater than that on the low-pressure side.

notes

The operating conditions used in this section of the clinic are approximate, subject to variation with changing load and cooling-water temperature conditions.

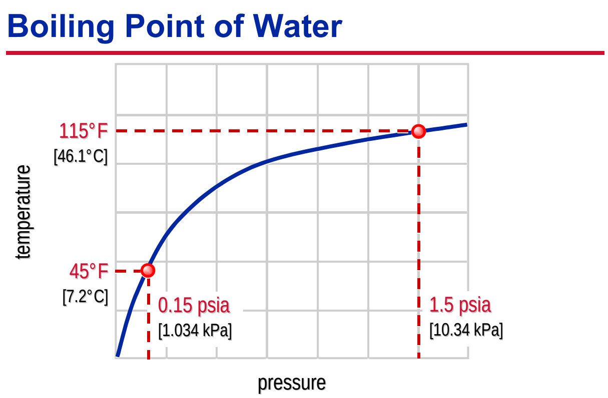

Figure 11

At a given pressure, the temperature at which a liquid will boil into a vapor is the same temperature at which the vapor will condense back into a liquid. This curve illustrates the pressures and corresponding temperatures at which water (the refrigerant) boils and condenses.

At atmospheric pressure (14.7 psia [101.3 kPa]), water boils and evaporates at 212 °F [100 °C]. When the pressure is decreased, water boils at a lower temperature. At the lower pressure, there is less force pushing against the water molecules, allowing them to separate easier.

Just like in the vapor-compression refrigeration cycle, this change in pressure allows the evaporator temperature to be low enough for the refrigerant to absorb heat from the water being cooled. Likewise, it allows the condenser temperature to be high enough for the refrigerant to reject heat to water at normally available temperatures. Inside of the evaporator, the pressure is very low, 0.15 psia [1.034 kPa] in this example, so that the refrigerant boils at 45 °F [7.2 °C]. In the condenser, however, the pressure is much higher (1.5 psia [10.34 kPa]) so that the refrigerant condenses at 115°F [46.1 °C].

period one
Absorption Refrigeration Cycle

notes

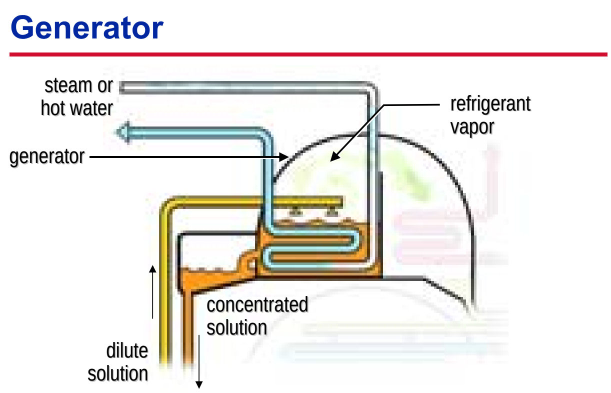

Figure 12

Starting on the high-pressure side of the cycle, the purpose of the **generator** is to deliver the refrigerant vapor to the rest of the system. It accomplishes this by separating the water (refrigerant) from the lithium bromide-and-water solution.

In the generator, a high-temperature energy source, typically steam or hot water, flows through tubes that are immersed in a dilute solution of refrigerant and absorbent. The solution absorbs heat from the warmer steam or water, causing the refrigerant to boil (vaporize) and separate from the absorbent solution. As the refrigerant is boiled away, or "generated," the absorbent solution becomes more concentrated.

The concentrated absorbent solution returns to the absorber and the refrigerant vapor migrates to the cooler condenser. Physically, the generator and condenser are contained inside of the same shell. The pressure in the condenser section is less than the pressure in the generator section. This is because the temperature of the cooling water flowing through the tubes of the condenser is less than the temperature of the steam or hot water flowing through the tubes of the generator.

notes

Condenser

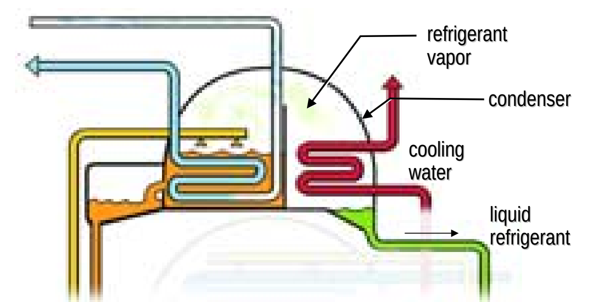

Figure 13

Inside the **condenser**, cooling water flows through tubes and the hot refrigerant vapor fills the surrounding space. As heat transfers from the refrigerant vapor to the water, refrigerant condenses on the tube surfaces. The condensed liquid refrigerant collects in the bottom of the condenser before traveling to the expansion device.

In absorption water chillers, the cooling water system is typically connected to a cooling tower.

Expansion Device

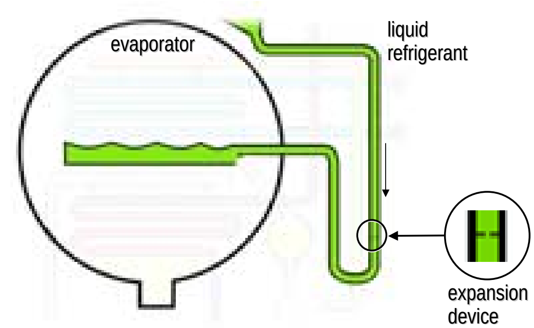

Figure 14

From the condenser, the liquid refrigerant flows through an **expansion device** into the evaporator. The expansion device is used to maintain the pressure difference between the high-pressure (condenser) and low-pressure (evaporator) sides of the refrigeration system. In this example, the expansion device is a throttling pipe, which is a long section of pipe with an orifice restriction in it. It creates a liquid seal that separates the high-pressure and low-pressure sides of the cycle.

notes

As the high-pressure liquid refrigerant flows through the expansion device, it causes a pressure drop that reduces the refrigerant pressure to that of the evaporator. This pressure reduction causes a small portion of the liquid refrigerant to boil off, or “flash,” cooling the remaining refrigerant to the desired evaporator temperature. The cooled mixture of liquid and vapor refrigerant then flows into the evaporator pan.

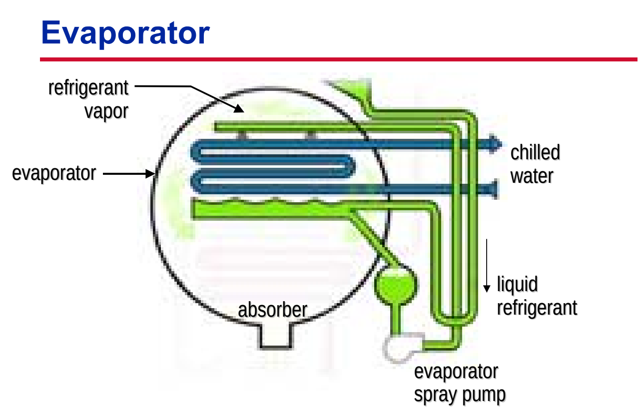

Figure 15

Inside the **evaporator**, relatively warm return water from the chilled-water system flows through the tubes. An **evaporator pump** draws the liquid refrigerant from the bottom of the evaporator and continuously circulates it to be sprayed over the tube surfaces. This maximizes heat transfer.

As heat transfers from the water to the cooler liquid refrigerant, the refrigerant boils (vaporizes) and the resulting refrigerant vapor is drawn into the lower-pressure absorber. Physically, the evaporator and absorber are contained inside the same shell.

notes

Absorber

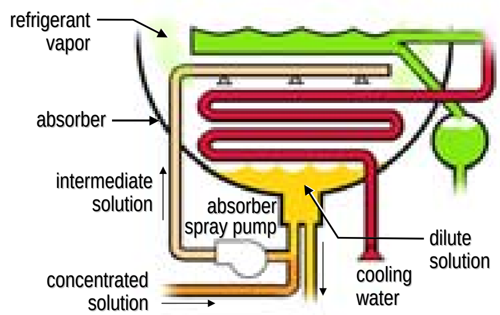

Figure 16

Inside the **absorber**, the refrigerant vapor is absorbed by the lithium bromide solution. As the refrigerant vapor is absorbed, it condenses from a vapor to a liquid, releasing the heat it acquired in the evaporator. This heat, along with the heat generated during the process of being absorbed, is rejected to the cooling water that is circulated through the absorber tube bundle. Absorption of the refrigerant vapor creates a low pressure area within the absorber. This lower pressure, along with the absorbent's affinity for water, induces a continuous flow of refrigerant vapor from the evaporator.

Maximum surface area is provided by spraying the solution over the tube bundle. This also provides maximum heat transfer to the cooling water. The **absorber spray pump** mixes concentrated absorbent solution (returning from the generator) with dilute solution (from the bottom of the absorber) and delivers this intermediate solution to the absorber sprays.

There are two reasons for using an intermediate solution rather than a concentrated solution in the absorber sprays. First, for effective tube wetting, a greater quantity of solution is required than is available from the generator. Therefore, dilute solution is mixed with the concentrated solution to increase the total quantity of solution being sprayed over the tube surfaces. Second, if concentrated solution were sprayed directly upon the absorber tube bundle, it would be subjected to temperatures that could cause it to crystallize—a solidification of the bromide salt. Therefore, the concentration is reduced by mixing it with dilute solution.

notes

Heat Exchanger

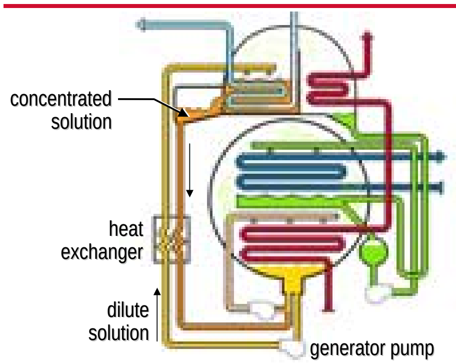

Figure 17

As the lithium bromide solution absorbs the refrigerant, it becomes diluted and has less ability to absorb water vapor. To complete the cycle and sustain operation, the absorbent solution must be reconcentrated. Consequently, the **generator pump** continuously returns the dilute solution to the generator to again separate the refrigerant vapor from the solution and reconcentrate the solution, thus repeating the cycle.

This cool dilute solution that is pumped from the absorber to the generator, and the hot concentrated solution returning from the generator, pass through a **heat exchanger**. This transfer of heat preheats the dilute solution, reducing the heat energy required to boil the refrigerant within the generator, and also precools the concentrated solution, reducing the required flow rate of cooling water through the absorber.

Notice that in this example cycle, the cooling water passes through the condenser after passing through the absorber. Some absorption chiller designs split the cooling water and deliver it directly to both the absorber and the condenser.

notes

Equilibrium Chart

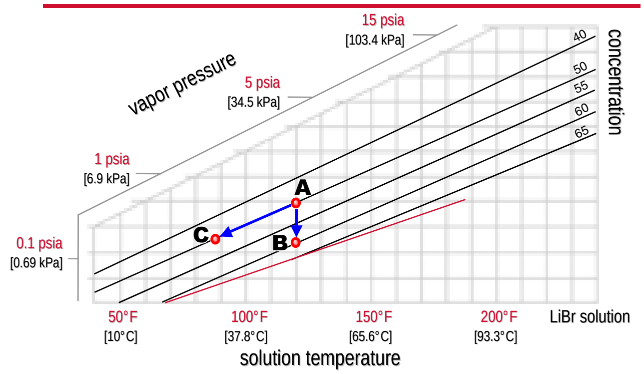

Figure 18

Equilibrium Chart

The performance of the absorption refrigeration cycle can be analyzed using a special chart called an *Equilibrium Chart for Aqueous Lithium Bromide Solutions*. This chart plots the vapor pressure (vertical axis) versus the temperature (horizontal axis) and concentration (diagonal lines) of the lithium bromide (LiBr) solution.

The chart shows that an increase in concentration (**A** to **B**), at a constant solution temperature, results in a decrease in vapor pressure. Conversely, a decrease in solution temperature (**A** to **C**), at a constant concentration, results in a decrease in vapor pressure. Assuming that no air or other noncondensables are inside the chiller, the vapor pressure of the solution determines the temperature at which the refrigerant will vaporize. In other words, the combination of solution temperature and concentration determines the temperature at which the refrigerant will boil (vaporize).

period one
Absorption Refrigeration Cycle

notes

Absorption Refrigeration Cycle

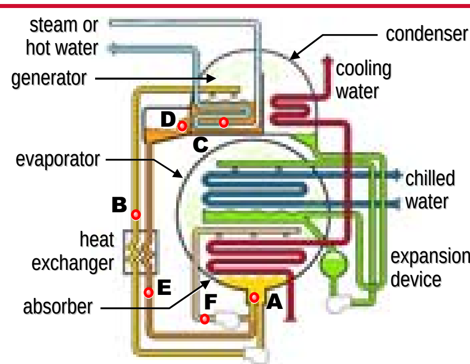

Figure 19

A diagram of a typical absorption refrigeration cycle can be superimposed on this equilibrium chart to demonstrate the function of each component in the system.

Realize that the equilibrium chart can only be used for those portions of the cycle where the lithium bromide solution is present. It cannot be used for the condenser or evaporator sections. The properties of the refrigerant as it passes through the condenser, expansion device, and evaporator can be analyzed using a pressure–enthalpy chart for the refrigerant (water, in this case).

notes

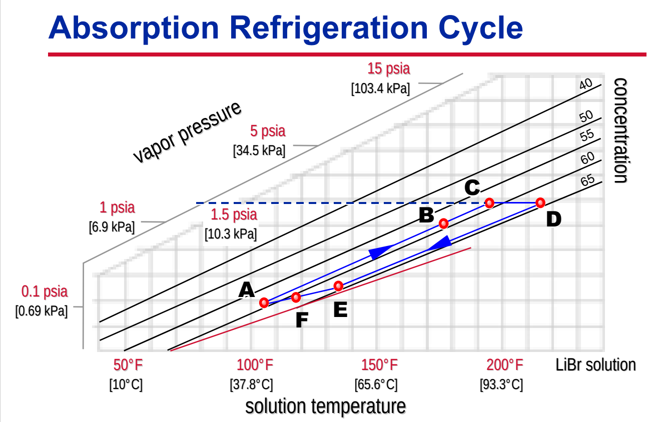

Figure 20

Starting at the absorber, the dilute lithium bromide solution leaves the absorber (**A**) at 105°F [40.6°C] and 59% concentration. This solution passes through the heat exchanger, where it is preheated to 175°F [79.4°C] (**B**). (Notice that there is no change in concentration as the solution passes through the heat exchanger.) In the generator, the solution absorbs heat from the steam or hot water flowing through the tubes. Initially, this only sensibly heats the solution to **C**, that is, the temperature of the solution increases while the concentration stays the same. At this point, the refrigerant begins to boil (vaporize) and separate from the solution. This increases the concentration of the lithium bromide solution as the temperature continues to increase (**D**).

The concentrated solution (**D**), now at 215°F [101.7°C] and 64.5%, passes through the heat exchanger where it is cooled to 135°F [57.2°C] (**E**). This cooled, concentrated solution (**E**) is then mixed with dilute solution from the absorber (**A**), and this intermediate solution (**F**) (118°F [47.8°C] and 62% concentration) is pumped to the absorber spray trees. In the absorber, refrigerant vapor is absorbed by the intermediate solution, decreasing its concentration to 59%, while heat is transferred to the cooling water. The resulting cooled, dilute solution (**A**) returns to the generator to repeat the cycle.

This chart also can be used to demonstrate the operating pressures of the cycle. In this example, the low-pressure sections of the cycle are operating at approximately 0.15 psia [1.034 kPa], and the high-pressure sections are operating at approximately 1.5 psia [10.34 kPa].

notes

Absorption Water Chillers

period two

Absorption Chiller Types

Figure 21

Lithium bromide-and-water absorption chillers are classified by the firing method—that is, how the primary generator is heated and whether it has a single- or a multiple-effect generator. Indirect-fired chillers are heated with steam or a hot liquid (such as water) that is typically supplied by an on-site boiler or a local utility. It can also be heated by waste energy that is recovered from the exhaust of a gas turbine or by some other heat recovery device. Direct-fired chillers are heated via the combustion of fossil fuels. An absorption chiller with a single generator is called a single-effect chiller. Multiple-effect chillers have multiple generators.

Like vapor-compression water chillers, absorption chillers can also be classified by the condensing method employed, either air-cooled or water-cooled. Physical size limitations typically constrain air-cooled condensing to ammonia-and-water absorption equipment that is applied in residential and small commercial applications (3 to 5 tons [10 to18 kW]). Most large commercial (20 to 1,500 tons [70 to 5,300 kW]) water-and-lithium bromide absorption chillers employ water-cooled condensing with cooling towers, because of the higher energy efficiency at design conditions.

notes

period two
Absorption Chiller Types

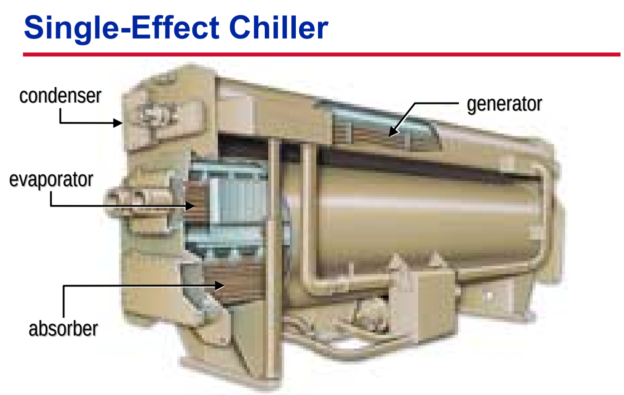

Figure 22

Single-Effect Chiller

The **single-effect** absorption water chiller uses a cycle similar to the one presented in Period One. It includes a single generator, condenser, evaporator, absorber, heat exchanger, and pumps.

These chillers are typically operated on low-pressure steam (approximately 15 psig [204.8 kPa]) or medium-temperature liquids (approximately 270°F [132.2°C]). Typical coefficients of performance for single-effect water chillers are 0.6 to 0.8. The **coefficient of performance** (COP) is a dimensionless ratio used to express the efficiency of a refrigeration machine. For an absorption water chiller, COP is defined as the ratio of evaporator cooling capacity divided by the heat energy required by the generator. A higher COP designates a higher efficiency.

Notice that the COP used to express the efficiency of absorption water chillers excludes the electrical energy needed to operate the pumps, purge, and controls.

period two
Absorption Chiller Types

notes

Single-Effect Chiller

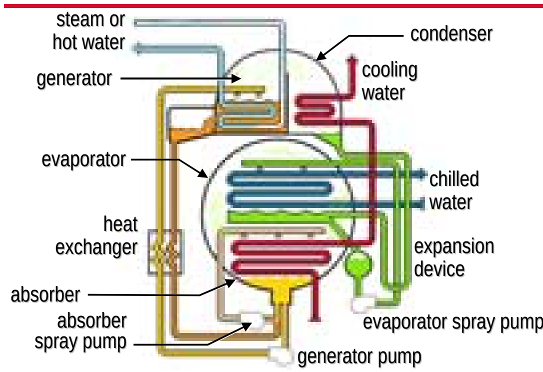

Figure 23

Let us review Period One briefly. In the **generator**, dilute solution absorbs heat from the steam or hot water, causing the refrigerant to boil and separate from the absorbent solution. As the refrigerant boils away, the absorbent solution becomes concentrated and returns to the absorber. The resulting hot refrigerant vapor migrates to the cooler **condenser**, where heat transfers from the refrigerant vapor to the cooling water, causing the refrigerant to condense. The resulting condensed liquid refrigerant flows through an **expansion device**, causing a pressure drop that reduces the refrigerant pressure and temperature to the desired evaporator conditions. The cooled mixture of liquid and vapor refrigerant then flows into the **evaporator** pan, from which the **evaporator spray pump** continuously pumps the liquid refrigerant and sprays it over the tubes. As heat transfers from the water to the cooler refrigerant, the refrigerant boils (vaporizes) and the resulting refrigerant vapor is drawn into the absorber.

Inside the **absorber**, the refrigerant vapor is absorbed by the lithium bromide solution. As the refrigerant vapor is absorbed, it is also condensed, thereby releasing heat to the cooling water. The **absorber spray pump** mixes concentrated absorbent solution (returning from the generator) with dilute solution (from inside the absorber) and delivers this intermediate solution to the absorber sprays. To complete the cycle, the **generator pump** returns the dilute absorbent solution to the generator to be reconcentrated. This cool dilute solution passes through a **heat exchanger** to be preheated by the hot concentrated solution returning from the generator.

notes

Double-Effect Chiller

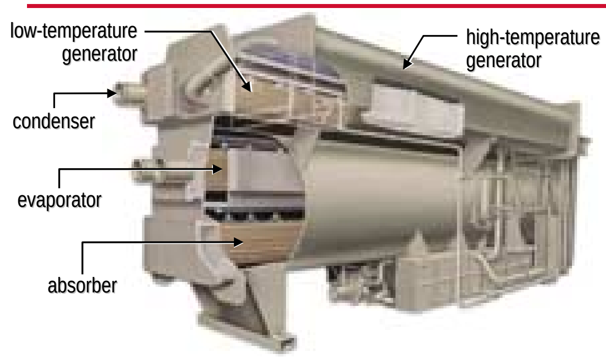

Figure 24

Double-Effect Chiller

The double-effect absorption chiller includes the same basic components as the single-effect chiller; however, it also includes an additional generator, heat exchanger, and pump.

The high-temperature generator can use steam or hot water (indirect-fired) as the energy source, or it can use the combustion of a fuel such as natural gas or oil (direct-fired). First we will discuss an indirect-fired, double-effect absorption chiller. The direct-fired chiller will be discussed later.

Indirect-fired, double-effect absorption chillers are typically operated on medium-pressure steam (approximately 115 psig [894.3 kPa]) or high-temperature liquids (approximately 370°F [187.8°C]). Typical COPs for these chillers are 0.9 to 1.2.

notes

Double-Effect Chiller

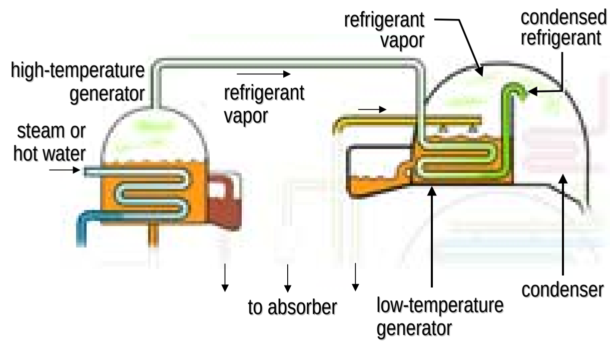

Figure 25

In the **high-temperature generator**, very high temperature steam or hot water flows through tubes that are immersed in an absorbent solution that is at an intermediate concentration. The solution absorbs heat from the warmer steam or water, causing the refrigerant to boil and separate from the absorbent solution. As the refrigerant boils away, the absorbent solution becomes concentrated and returns to the absorber.

The hot refrigerant vapor produced in the high-temperature generator migrates to the **low-temperature generator**, where it flows through tubes that are immersed in a dilute solution. The solution absorbs heat from the high-temperature refrigerant vapor, causing the refrigerant in the low-temperature generator to boil and separate from the absorbent solution. As that refrigerant boils away, the concentration of the absorbent solution increases and it returns to the absorber.

The low-temperature refrigerant vapor produced in the low-temperature generator migrates to the cooler condenser. Additionally, the liquid refrigerant that condensed inside the tubes of the low-temperature generator also flows into the condenser.

notes

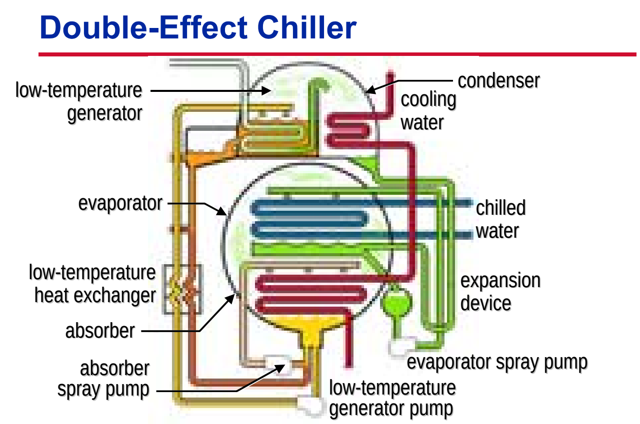

Figure 26

Next, the refrigerant travels through the condenser, expansion device, evaporator and absorber in a manner similar to refrigerant travel in the single-effect absorption chiller.

The **low-temperature generator pump** returns the dilute absorbent solution to the low-temperature generator to be reconcentrated. This cool dilute solution passes through the **low-temperature heat exchanger** to be preheated by the hot concentrated solution returning from the two generators.

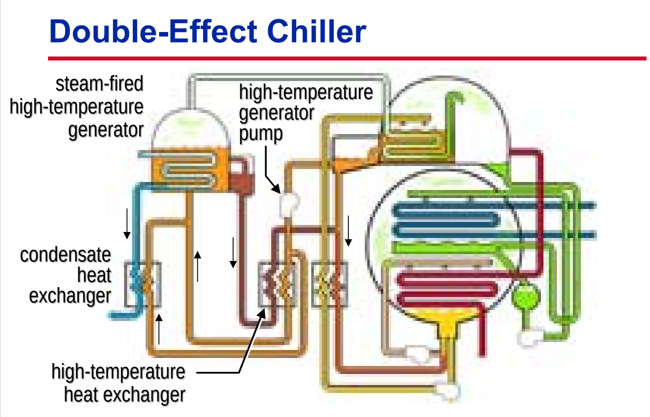

Figure 27

The **high-temperature generator pump** draws a portion of the intermediate solution from the low-temperature generator and delivers it to the high-temperature generator to be reconcentrated. Some of this cooler intermediate solution passes through the **high-temperature heat exchanger** to be preheated by the hot concentrated solution coming from the high-temperature generator. This reduces the heat energy required to boil the refrigerant inside of the high-temperature generator. Precooling the concentrated solution returning

notes

to the absorber reduces the flow rate of cooling water required through the absorber.

The chiller shown in Figure 27 is steam-fired and includes an additional heat exchanger. This **condensate heat exchanger** transfers heat from the hot condensed steam, leaving the high-temperature generator, to the cooler intermediate solution returning to the high-temperature generator. Notice that this heat exchanger is in parallel with the high-temperature heat exchanger and only a portion of the intermediate solution passes through each one. Again, a double-effect absorption chiller operating with hot water would not include the condensate heat exchanger.

The precooled, concentrated solution leaving the high-temperature heat exchanger then mixes with the rest of the intermediate solution that is returning from the low-temperature generator, before traveling to the low-temperature heat exchanger.

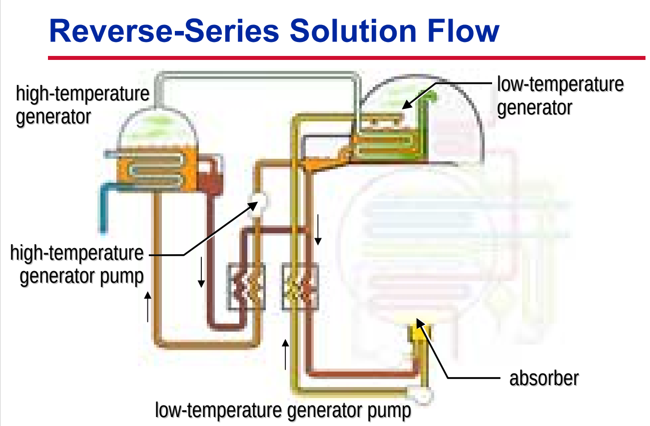

Figure 28

All double-effect absorption chillers are constructed from the same basic components: high-temperature generator, low-temperature generator, condenser, evaporator, absorber, two solution heat exchangers, and several pumps. There are, however, three common methods in which the solution can be circulated through the chiller: series, parallel, and reverse-series. The double-effect chiller used in the previous example employs the reverse-series flow cycle.

In a **reverse-series flow** cycle, the dilute solution leaving the absorber is pumped to the low-temperature generator, where it is partially concentrated. Part of this intermediate solution is then pumped to the high-temperature generator, where it is further concentrated. The remaining intermediate solution, leaving the low-temperature generator, is mixed with the concentrated solution, leaving the high-temperature generator, before returning to the absorber.

The reverse-series flow cycle requires two generator pumps. This, however, makes it easier to control in part-load conditions.

notes

Series Solution Flow

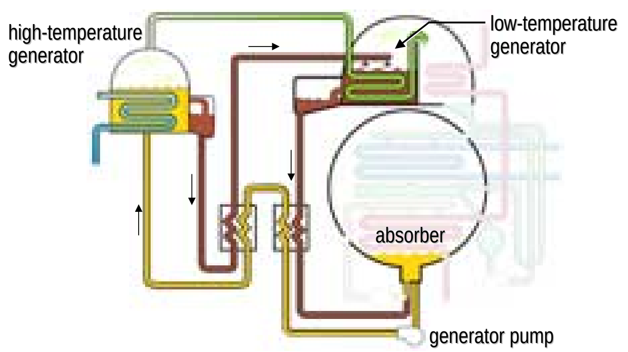

Figure 29

In the **series flow** cycle, the dilute solution from the absorber is pumped entirely to the high-temperature generator. As the refrigerant boils away and migrates to the low-temperature generator, the absorbent solution becomes concentrated. The resulting intermediate solution then flows to the low-temperature generator, where it is further concentrated by the refrigerant vapor that was created in the high-temperature generator. The concentrated solution then flows back to the absorber to repeat the cycle.

The series flow cycle has been the mainstay of most double-effect absorption chiller designs for many years. It is simple because it requires only one generator pump and is fairly straightforward to control. The series cycle, however, requires a significantly larger heat exchanger to obtain similar COPs to the other cycles.

notes

Parallel Solution Flow

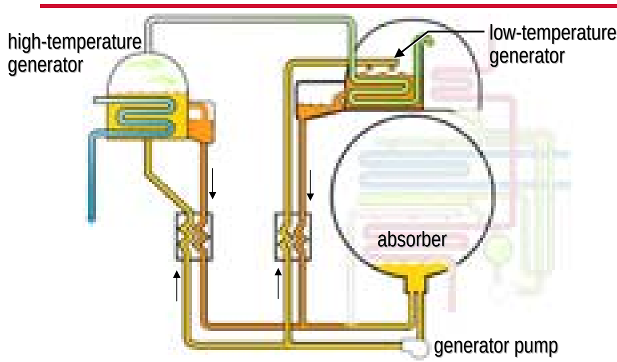

Figure 30

In the **parallel flow** cycle, the dilute solution from the absorber is split between the low-temperature and high-temperature generators. Both streams of dilute solution are concentrated in the generators and mix together again before returning to the absorber. The parallel flow cycle can be implemented using one generator pump (as shown in Figure 30) if a throttling device is used to control the flow of solution to the low-temperature generator. Separate generator pumps should be used for control over the full range of operating conditions.

In the end, the performance of a double-effect absorption chiller has little to do with the flow cycle employed. Instead, the performance depends on the choice of operating conditions, the amount of heat transfer surface area, the effectiveness of the purge system, the materials of construction, the design of the controls, and the manufacturing techniques.

notes

Direct-Fired Chiller

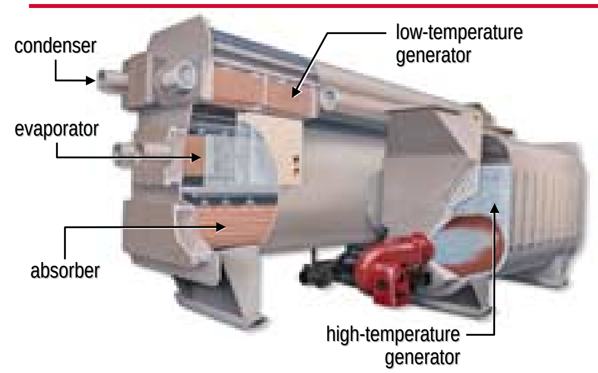

Figure 31

Direct-Fired Chiller

The indirect-fired absorption chillers discussed previously use steam or a hot liquid (such as water) as the energy source. In contrast, the high-temperature generator of a direct-fired absorption chiller uses the heat released by the combustion of a fossil fuel to boil off the refrigerant vapor.

Common fuels used to fire the burner in the high-temperature generator are natural gas, number 2 fuel oil, or liquid petroleum (LP). Additionally, combination burners are available that can be switched from one fuel to another. Typical COPs for direct-fired, double-effect chillers are 0.9 to 1.1 (based on the higher heating value, or HHV, of the fuel).

Direct-Fired Chiller

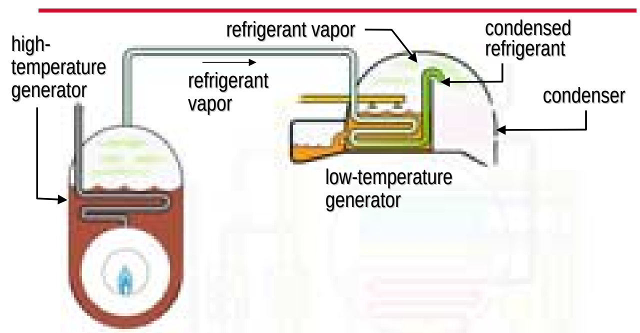

Figure 32

The example direct-fired chiller shown here employs the reverse-series flow cycle. In the **high-temperature generator**, the intermediate solution absorbs heat that is generated by the combustion process. Similar to the indirect-fired, double-effect chiller, this transfer of heat causes the refrigerant to boil and

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separate from the absorbent solution. As the refrigerant boils away, the solution becomes concentrated and returns to the absorber.

The hot refrigerant vapor produced in the high-temperature generator migrates to the **low-temperature generator** where it flows through the tubes that are immersed in a dilute solution. The solution absorbs heat from the high-temperature refrigerant vapor, causing the refrigerant in the low-temperature generator to boil and separate from the absorbent solution. As that refrigerant boils away, the concentration of the solution increases and it returns to the absorber.

The low-temperature refrigerant vapor produced in the low-temperature generator migrates to the cooler condenser. Additionally, the liquid refrigerant that condensed inside the tubes of the low-temperature generator flows into the condenser.

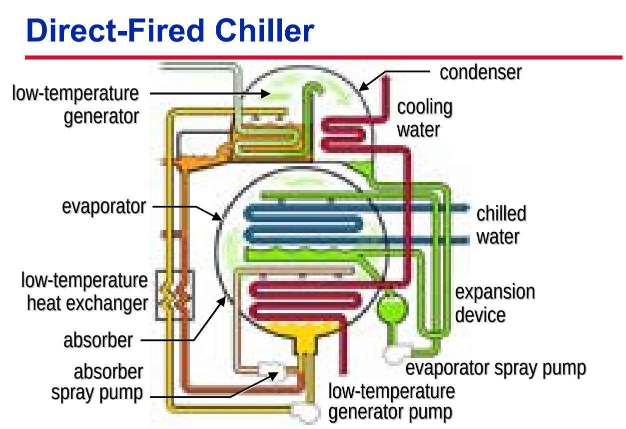

Figure 33

Next, the refrigerant travels through the condenser, expansion device, evaporator, and absorber in a manner similar to refrigerant travel in the indirect-fired double-effect absorption chiller.

The **low-temperature generator pump** returns the dilute absorbent solution to the low-temperature generator to be reconcentrated. This cool dilute solution passes through the **low-temperature heat exchanger** to be preheated by the hot concentrated solution returning from the two generators.

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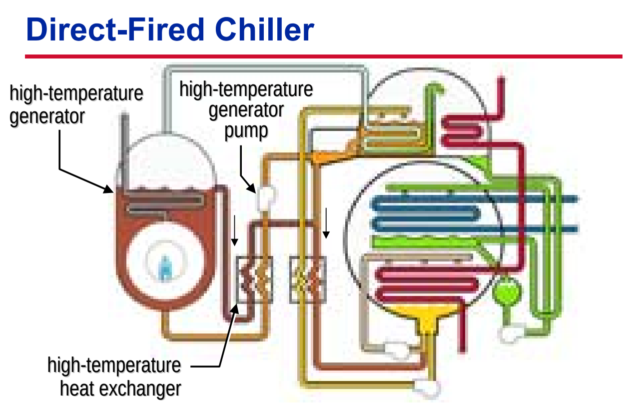

Figure 34

The **high-temperature generator pump** draws a portion of the intermediate solution from the low-temperature generator and delivers it to the high-temperature generator to be reconcentrated.

This cooler intermediate solution passes through the **high-temperature heat exchanger** to be preheated by the hot concentrated solution returning from the high-temperature generator. This reduces the heat energy required to boil the refrigerant inside the high-temperature generator. Precooling the concentrated solution returning to the absorber reduces the flow rate of cooling water required through the absorber.

The precooled, concentrated solution leaving the high-temperature heat exchanger then mixes with the rest of the intermediate solution that is returning from the low-temperature generator, before traveling to the low-temperature heat exchanger.

notes

Chiller/Heater

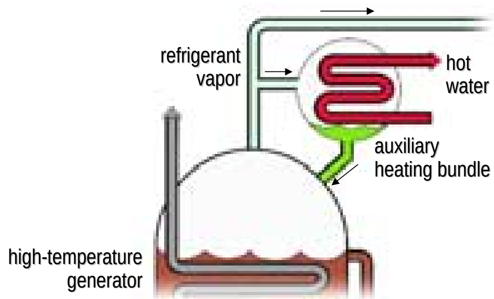

Figure 35

Chiller/Heater

One of the benefits of a direct-fired absorption chiller is that it can be used to provide both cooling and heating. These chillers, therefore, can be installed in systems to supplement, or even replace, primary heating or domestic hot water equipment. This can free up equipment-room space that was required for this heating equipment.

In the direct-fired absorption chiller shown here, an **auxiliary heating bundle** can be added, allowing the chiller to make hot water as well as chilled water. The auxiliary heating bundle draws in a portion of the refrigerant vapor leaving the high-temperature generator. Water flowing through the tubes absorbs heat from this hot refrigerant vapor, causing the refrigerant to condense on the tube surfaces. This transfer of heat warms the water to a temperature where it can be used for comfort heating, domestic hot water needs, or process heating loads.

The key advantage of this design is that it can be configured to operate in cooling only, heating only, or simultaneous cooling/heating modes. For simultaneous operation, however, two separate sets of pipes are needed to deliver chilled and hot water to the system.

notes

Chiller/Heater Operating Modes

- **Cooling only**
- **Heating only**
- **Simultaneous cooling/heating – cooling priority**
- **Simultaneous heating/cooling – heating priority**

Figure 36

Each of these operating modes serves a different load requirement.

- In **cooling only** mode, the absorption chiller operates exactly like the standard chiller offering. Its function is to make cold water.
- In **heating only** mode, the only function of the chiller is to make hot water.
- In **simultaneous cooling/heating – cooling priority** mode, the primary function of the chiller is to make cold water. The heating function is secondary and will be performed only if there is excess capacity (burner fire).
- In **simultaneous heating/cooling – heating priority** mode, the primary function of the chiller is to make hot water. The cooling function is secondary and will be performed only if there is excess capacity (burner fire).

When providing cooling, this type of direct-fired absorption chiller can only supply a limited amount of heat, dependent on the current cooling load. If the heating and cooling loads for a particular application are substantial and simultaneous, it may be best to use this chiller to supplement, instead of replace, the main heating equipment.

notes

Chiller/Heater

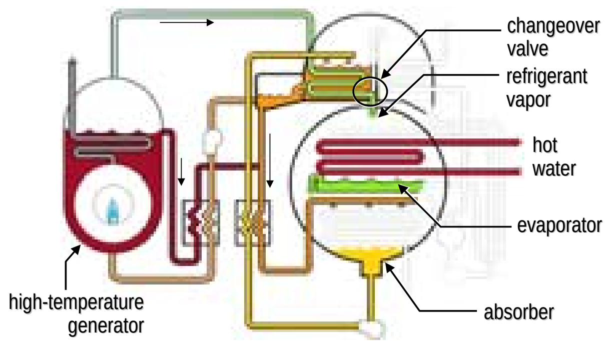

Figure 37

An alternate method is to use the evaporator as a condenser in the heating mode. In this example chiller, by switching the cooling/heating changeover valve the chiller switches to heating mode, and hot water can be delivered using the same piping system that was used to supply chilled water in the cooling mode. The cooling tower and refrigerant pumps can typically be shut off.

In the direct-fired high-temperature generator, heat that is generated by the combustion process causes the refrigerant to boil and separate from the absorbent solution. As the refrigerant boils away, the absorbent solution becomes concentrated and returns to the absorber.

The refrigerant vapor produced by the high-temperature generator flows into the evaporator. Heat is transferred from the hot refrigerant vapor to the water flowing inside the evaporator tubes, causing the refrigerant to condense on the tube bundle and fall into the evaporator pan. This condensed liquid refrigerant then overflows into the absorber section where it is absorbed by the lithium bromide solution.

The resulting dilute absorbent solution is preheated as it is pumped through the low- and high-temperature heat exchangers, eventually returning to the high-temperature generator to repeat the cycle.

The advantage of this design is that no additional bundle is required for heating mode. This chiller, however, can only operate in cooling mode or heating mode—no simultaneous operation is possible.

notes

Higher-Effect Chillers

- **Higher COPs**
- **Difficulties with implementation include:**
  - Problems with solution stability
  - Increased risk of corrosion problems
  - More expensive pressure vessel design requirements
  - Greater first cost due to added components
  - Larger physical size

Figure 38

While they are presently not available, higher-effect absorption chillers are being studied for commercial use due their potential for higher COPs. Typical COPs for these triple-effect cycles are 1.4 to 1.5. Implementation of these cycles into commercial water chillers, however, includes difficulties such as the following.

- Higher solution temperatures create problems with stability of the absorbent solution and performance additives, as well as additional material corrosion problems.
- In some cases, higher operating pressures which require high-cost pressure vessel designs.
- Greater first cost due to the need for additional pumps and heat exchangers.
- Larger physical size.

As mentioned earlier, other cycles and fluid combinations are also being studied for commercial use. The focus of this clinic, however, is limited to water chillers that use a lithium bromide-and-water solution.

notes

Absorption Water Chillers

period three
Capacity Control

Figure 39

The primary objective of the chiller capacity control system is to reliably maintain the temperature of the chilled water leaving the evaporator. The control system monitors the temperature of the leaving chilled water, compares it to the setpoint, and adjusts the amount of solution supplied to the generator and the heat input to the generator.

Equilibrium Chart

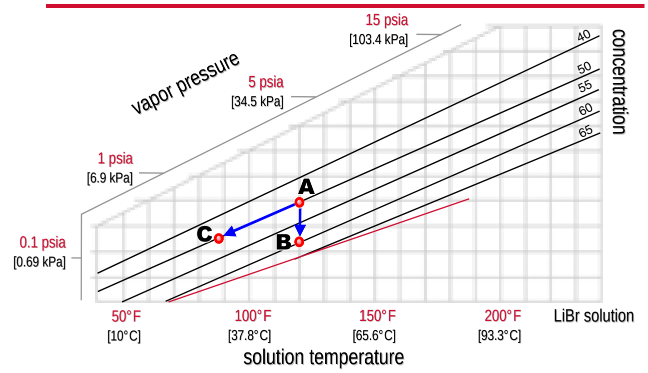

Figure 40

In Period One, the *Equilibrium Chart for Aqueous Lithium Bromide Solutions* was introduced to explain how the combination of solution temperature and concentration determines the pressure, and temperature, at which the refrigerant will boil (vaporize) in the evaporator. Recall that an increase in solution concentration (**A** to **B**), at a constant temperature, results in a decrease in vapor pressure. Conversely, a decrease in solution temperature (**A** to **C**), at a constant concentration, results in a decrease in vapor pressure. Assuming that no air or other noncondensables are inside the chiller, the vapor pressure of the solution determines the temperature at which the refrigerant will vaporize. In

notes

other words, the combination of solution temperature and concentration determines the temperature at which the refrigerant will boil (vaporize).

Varying the temperature at which the refrigerant boils in the evaporator changes the capacity of the absorption water chiller. So, in order to control the capacity of the chiller to meet the ever-changing system loads, either the solution temperature or the solution concentration must be varied. Many chiller control strategies vary both simultaneously.

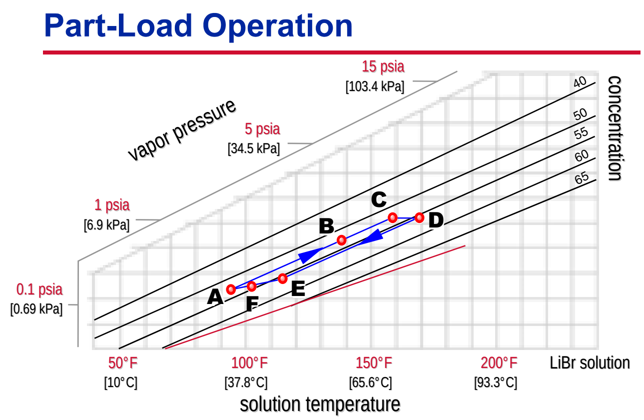

Figure 41

A common method used to vary the temperature of the solution is to vary the amount of absorbent solution delivered to the generator. At part load, in response to a changing leaving-chilled-water temperature, less dilute solution is pumped to the generator, reducing the heat energy required to boil off the refrigerant vapor. Reduced heat input results in less refrigerant boiled off (vaporized) in the generator and a less-concentrated solution returning to the absorber (**D**, 56% shown here at part load versus 64.5% at full load shown in Figure 20). This less-concentrated solution has a lower affinity for water vapor and, therefore, the pressure inside the absorber–evaporator sections increases (pressures at **A** and **F**). This increased pressure causes the refrigerant inside the evaporator to boil at a higher temperature, reducing the temperature difference between the chilled water and the refrigerant, thus reducing the chiller's capacity.

Because less refrigerant is boiled off in the generator, the refrigerant flow rate through the cycle is decreased. Consequently, the heat rejected within the absorber is less. Less heat rejected by the cooling tower typically results in lower-temperature water returning from the tower, which tends to increase the capacity of the chiller and further reduces heat input to the generator.

Varying the solution flow to the generator can be accomplished in several ways. Historically, it has been common to use either a throttling valve or a bypass valve. A throttling valve creates an additional flow restriction in the pipe from the absorber to the generator, allowing the solution pump to ride up its pump curve, reducing the flow rate. A bypass valve diverts a portion of the solution back into the absorber, thus reducing the flow to the generator.

notes

Vary Solution Flow to Generator

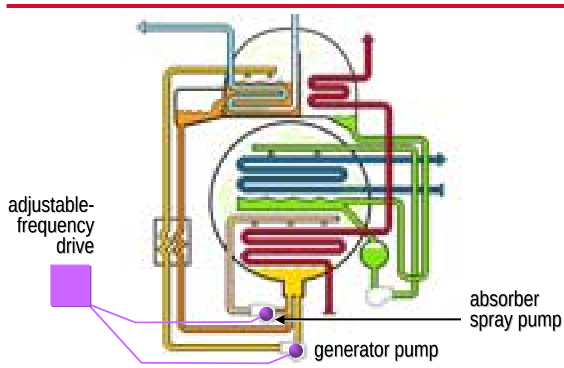

Figure 42

In more modern absorption chiller designs, **adjustable-frequency drives (AFD)**, also known as variable-speed drives, are used to vary the speed of the generator pump motor, thus reducing the flow of solution to the generator. AFDs have the added benefit of saving pump energy at part-load conditions.

Vary Heat Input to Generator

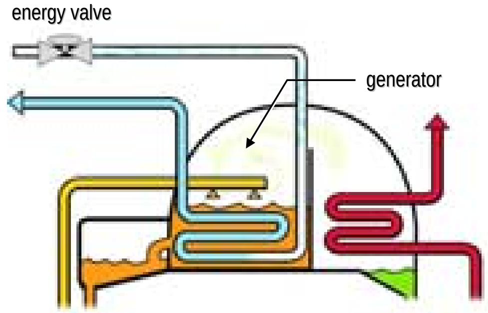

Figure 43

In order to vary the solution concentration, absorption chillers vary the heat input to the generator. This figure shows a modulating energy valve on a single-effect, steam absorption chiller. At part load, in response to a changing leaving-chilled-water temperature, the energy valve begins to close, reducing the amount of heat input to the generator. Similarly, on a direct-fired absorption chiller, the amount of heat input to the generator is varied by modulating the capacity of the burner.

While the solution flow to the generator is varied to maintain the desired chilled-water temperature, the heat input to the generator is varied to control the solution concentration. This assures optimal efficiency and keeps the chiller

notes

out of the condition called crystallization—a solidification of the bromide salt. Crystallization will be discussed next.

In the past, absorption water chillers would vary the heat input to the generator as the primary means of maintaining the desired leaving-chilled-water temperature. Because the absorption refrigeration cycle has the capability to store energy, using the energy valve as the sole method of control would cause the chiller to react very slowly to a change in capacity. By varying the flow rate of solution to the generator and absorber sprays, especially with the use of adjustable-frequency drives, recent chiller designs are now able to react very quickly to ever-changing load and cooling-water conditions.

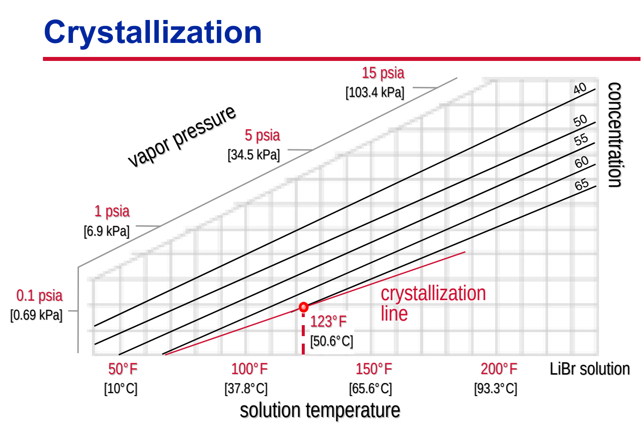

Figure 44

Crystallization

Lithium bromide is chemically classified as a salt. In its solid state, it has a crystalline structure and, like most salts, is soluble in water. With any salt solution, there is a "saturation" temperature for a given concentration, below which the salt begins to leave the solution as a solid. This is called **crystallization**.

The saturation temperature for various solution concentrations is represented by the crystallization line on the equilibrium chart. For example, consider a lithium bromide solution of 65% concentration. Above 123°F [50.6°C], all salt remains dissolved in the solution. If, however, the solution concentration remains the same and the temperature falls below 123°F [50.6°C], the solution becomes saturated—meaning that the solution contains more salt than it can hold at that temperature—and the salt begins to leave the solution in a solid crystalline form.

TRANE

period three
Capacity Control

notes

Crystallization

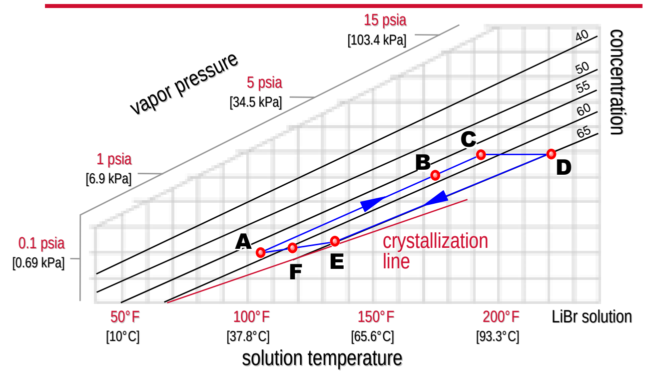

Figure 45

By plotting the single-effect absorption refrigeration cycle on the equilibrium chart, it is apparent that crystallization is most likely to occur in the heat exchanger. At this particular condition, the 65% concentrated solution (**D**) is cooled to 135°F [57.2°C] (**E**) as it passes through the heat exchanger. As noted previously, the saturation temperature of 65% solution is 123°F [50.6°C] so there is no danger of crystallization.

Consider, however, if the solution was instead 66% concentrated and cooled to the same 135°F [57.2°C] temperature. The saturation temperature for 66% concentrated solution is approximately 143°F [61.7°C]. The result would be a deposit of salt crystals inside the heat exchanger. Prolonged operation at this condition could result in a buildup of salt that would eventually block the passages through the heat exchanger, interrupting the operation of the chiller.

Once a chiller is crystallized, operation can only be resumed after the solution temperature is raised above its saturation temperature, above 143°F [61.7°C] in this example. At this higher temperature, the salt crystals would return to the solution, allowing the chiller to operate again.

With the advent of microelectronic controls, modern absorption water chillers are designed to monitor and control solution concentrations and temperatures, allowing the chiller to operate over a broad range of conditions without danger of crystallization. In addition, safety controls are available to avoid crystallization and even to de-crystallize the chiller if necessary. Therefore, crystallization is not the serious problem that it once was with absorption chillers.

notes

Causes of Crystallization

- Air and noncondensables leaking into the chiller
- Cooling water that is too cold or fluctuates in temperature too rapidly
- Electric power failure

Figure 46

As discussed, the point at which crystallization occurs is determined by the temperature and concentration of the concentrated solution inside the heat exchanger.

There are generally three possible causes of crystallization in an absorption water chiller:

- Air and other noncondensables leaking into the chiller
- Cooling water that is too cold or that fluctuates in temperature too rapidly
- An electric power failure

These will be discussed in the following figures.

Air Leaking Into the Chiller

- Increases evaporator pressure and temperature
- Decreases chiller capacity
- Increases heat input
- Increases concentration
- Especially under high-load conditions, could cause crystallization

Figure 47

Probably the most frequent cause of crystallization is that air and other noncondensables leak into the chiller. Because the operating pressures inside the absorption chiller are less than the atmospheric pressure, air wants to force

notes

its way into the chiller through any available path. As explained earlier, the pressure and temperature inside the evaporator are determined by the concentration and temperature of the solution in the absorber. If air leaks into the chiller, however, the evaporator pressure increases because a portion of the volume inside the evaporator–absorber sections is taken up by air, which is not absorbed by the lithium bromide solution. This increase in the evaporator pressure results in higher evaporator temperatures and decreased capacities.

Sensing the increasing temperature of the chilled water leaving the evaporator, the chiller control system attempts to overcome the condition by increasing the amount of solution delivered to the generator and by increasing the amount of heat input to the generator. This causes more refrigerant to be boiled off in the generator and results in a more concentrated solution being delivered to the heat exchanger. Under higher load conditions, it is possible to increase this solution concentration to the point where crystallization occurs in the heat exchanger.

In most modern absorption chillers, high-quality construction, smart microelectronic controls, and automatic purge systems are extremely effective in removing air from inside the chiller, maintaining chiller capacity, and avoiding crystallization. Any leaks, however, should be addressed immediately.

Cooling Water That is Too Cold

- **Lower cooling water temperature combined with high load...**
  - Decreases temperature of dilute solution traveling to generator
  - Results in lower temperature of concentrated solution returning to absorber
  - Causes concentrated solution inside heat exchanger to crystallize

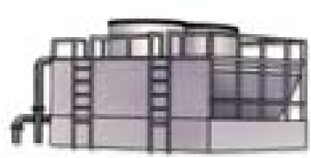

Figure 48

Cooling water that is too cold, combined with a high load on the chiller, is another possible cause of crystallization. Colder cooling water causes the temperature of the dilute solution travelling from the absorber to the generator to drop. This cool dilute solution entering the heat exchanger absorbs a greater amount of heat from the concentrated solution and, therefore, results in a lower temperature of concentrated solution leaving the heat exchanger. If the temperature drops low enough, crystallization of the concentrated solution can occur.

In the past, absorption chillers were designed to operate with constant-temperature cooling water. With these chillers, a sudden drop in the temperature of the cooling water could result in crystallization. The microelectronic controls for many modern absorption chillers are designed to

notes

operate over a wide cooling-water temperature range, allowing the cooling-water temperature to vary with the load and ambient conditions without the risk of crystallization. For optimum control of leaving-chilled-water temperature, however, it is still generally recommended to design the system to minimize the rate at which the cooling-water temperature varies.

Electric Power Failure

- Normal shutdown allows for dilution cycle, which reduces the concentration throughout the chiller
- Electric power failure does not allow dilution cycle
- Chiller could experience crystallization as it cools off

Figure 49

During normal shutdown, an absorption chiller goes through a dilution cycle to reduce the concentration of the solution throughout the chiller. At this reduced concentration, the chiller may cool off due to lower temperatures of the space surrounding the chiller, but it will not be in danger of crystallizing.

In the event of a power failure, the chiller is not able to go through the normal dilution cycle. As the chiller cools down, those sections of the chiller that contain highly concentrated solution may crystallize. This is most likely to happen if the chiller is operating at or near full load prior to the power failure. Additionally, the probability of crystallization becomes greater the longer the chiller is without power and the cooler the temperature is in the equipment room.

Today, chiller manufacturers use a variety of methods to ensure that the solution is diluted in case of an electric power failure. One method uses a combination of normally-open valves that allow refrigerant to flow, by gravity, and mix with the concentrated solution.

In summary, the high-quality construction, smart microelectronic controls, and automatic purge systems of most modern absorption chillers have improved the monitoring and control of the cycle, to the point where crystallization is not the serious problem that it once was with absorption chillers.

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De-Crystallization

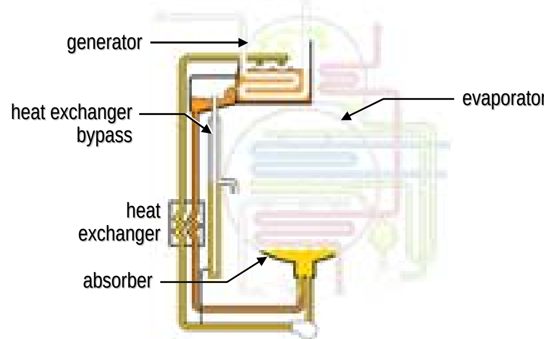

Figure 50

As a second line of defense, most absorption water chillers include devices that allow the chiller to recover in the event that crystallization does occur. Some of these devices simply sense impending crystallization, put the chiller through a dilution cycle, and shut the chiller down. Other devices keep the chiller operating while regaining control of the solution temperature and concentration.

The device shown in the figure above is a heat exchanger bypass that allows the chiller to de-crystallize and continue to operate. If crystallization does occur, the heat exchanger begins to be blocked, and the flow of concentrated solution from the generator to the absorber is reduced. Dilute solution, however, continues to flow from the absorber to the generator, resulting in concentrated solution backing up inside the generator.

This backed-up solution will eventually rise enough that the concentrated solution spills over into the bypass pipe and returns directly to the absorber, bypassing the heat exchanger. As a result, the temperature of the solution in the absorber is increased, approaching the temperature in the generator. As this warmer solution flows from the absorber, through the heat exchanger, to the generator, it raises the temperature of the heat exchanger and de-crystallization occurs.

notes

Low-Load Controls

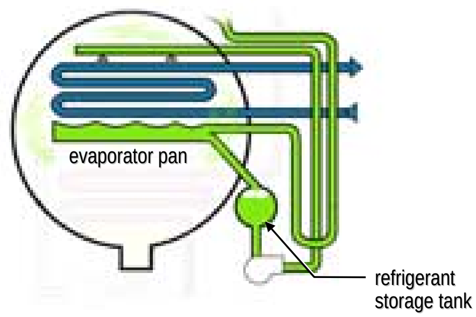

Figure 51

Special consideration must be given to controlling the chiller at very low load conditions combined with low cooling water temperatures. Under these conditions, the chiller reaches equilibrium with a very low solution concentration in the absorber. There is a possibility that the chiller might not have enough refrigerant to dilute the solution this much. As a result, the lithium bromide solution absorbs all of the refrigerant in an attempt to achieve this very dilute concentration, causing the evaporator to run dry.

The loss of refrigerant from the evaporator automatically stops the chiller. Additionally, if refrigerant is used to cool and lubricate the pump motors, a safety switch may shut the chiller off to protect the motor and pump.

One solution to this problem is to charge the chiller with additional refrigerant. During operation, this extra refrigerant is simply stored in the evaporator pan or a supplemental storage tank where it has no adverse effect on chiller operation. When low-load and cold-cooling-water conditions are encountered, this additional amount of refrigerant is available to effectively dilute the solution in the absorber. This allows the chiller to operate throughout its capacity range without the need for additional control devices.

An alternative solution is the use of controls to avoid this potential problem area. A float arrangement can be used to sense a low level of refrigerant in the evaporator, and in response, open a valve to divert solution from the absorber sprays directly back into the absorber sump. This reduces chiller capacity by slowing the rate of absorption and, therefore, the rate at which refrigerant is vaporized inside the evaporator.

notes

Purge System

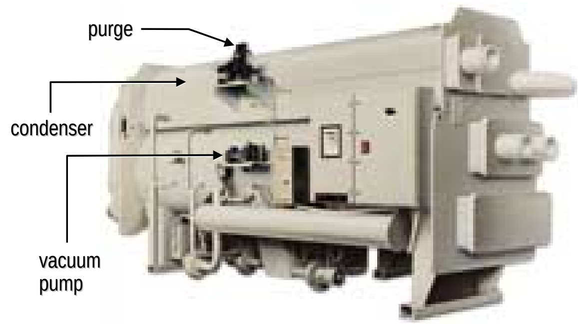

Figure 52

Purge System

As presented earlier, the accumulation of air and other noncondensable gases undermines the efficiency and reliability of the absorption chiller. Since absorption chillers operate below atmospheric pressure, regular operation of a **purge system** is required to remove, or "purge," the air and other noncondensables that may leak into the chiller. This is necessary to maintain the pressures and temperatures within the chiller for maximum efficiency. The purge system is also used for early detection of leaks.

notes

Purge Operation

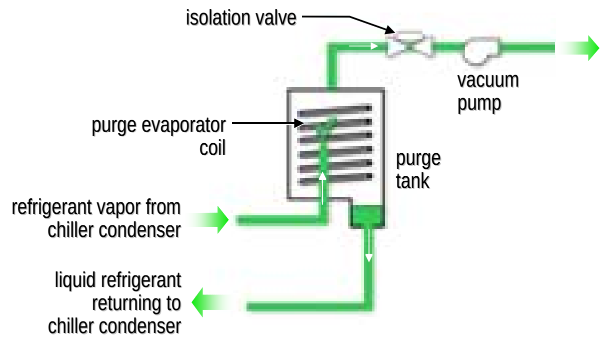

Figure 53

This example purge system consists of a purge tank, a small refrigeration system, a pump-out system, and controls. The purge's refrigeration system includes: a small compressor, an air-cooled condensing coil, an expansion valve, and an evaporator coil located inside of the purge tank.

When the chiller is operating, air migrates to the absorber, the area of the chiller operating at the lowest pressure. In this example purge system, an eductor system moves the air from the absorber to the condenser. Because the purge evaporator operates at a lower temperature and pressure than the chiller condenser, a mixture of refrigerant vapor and air is drawn from the chiller condenser into the purge tank. Inside the purge tank, the refrigerant condenses on the cold tubes of the evaporator coil, collects in the bottom of the purge tank, and returns to the chiller condenser as a liquid.

The air does not condense, but instead accumulates in the top portion of the purge tank. Eventually, enough air accumulates to cover a large portion of the purge evaporator coil. The air insulates this coil, impeding heat transfer and reducing the temperature of the refrigerant inside the purge evaporator coil. When the purge refrigerant temperature drops below the setpoint, a controller signals the need for a pump-out sequence. The controller opens the isolation valves, allowing the air to be pumped out of the purge by a vacuum pump. When the purge refrigerant temperature rises again, the controller closes the isolation valves.

The purge controls can be used to track and record how often pump-out occurs. Excessive purging activity may indicate an air leak or depletion of the corrosion inhibitor. The results can be decreased capacity, increased risk of internal corrosion, and possible crystallization. Leaks can be detected early by comparing pump-out activity over the last 24 hours to the 30-day average.

period four
Maintenance Considerations

notes

Absorption Water Chillers

period four

Maintenance Considerations

Figure 54

Today, after an absorption chiller is installed and put into operation, it functions without a full-time attendant. In most cases, the chiller starts and stops on a schedule controlled by a building automation system or a simple time clock.

Water chillers are designed for maximum reliability with a minimum amount of maintenance. Like all large mechanical systems, however, certain routine maintenance procedures are recommended. Periodic inspection of the purge system, cooling tower, fluid levels, heat transfer surfaces, energy supply, and pumps helps to maintain the absorption water chiller in peak operating condition. This period discusses these general maintenance requirements of absorption water chillers.

Operating Log

- Chilled water inlet and outlet temperatures and pressures
- Cooling water inlet and outlet temperatures and pressures
- Absorber inlet and outlet solution temperatures and concentrations
- Absorber spray solution temperature
- Generator inlet and outlet solution temperatures
- Evaporator refrigerant temperature
- Condenser refrigerant temperature
- Crystallization margin
- Purge pump-out activity
- Gas supply pressure (direct-fired)

Figure 55

Chiller operation should be checked daily and recorded in an operating log. Standard operating logs include: solution data; evaporator, absorber, and

notes

condenser inlet and outlet temperatures; and purge operation. Logs are a valuable tool for determining the onset of system problems.

This data may be obtained either manually or in conjunction with a building automation system. The chiller controller should be capable of providing this information quickly and easily. An automated control system is an efficient way to identify operating changes and schedule maintenance before they become a problem.

Mechanical Components

- **Recommended maintenance**
  - Pump teardown and inspection every 5 to 10 years
  - Controls: no maintenance or calibration required
  - Visually inspect overall unit
  - Inspect safety controls and electrical components

Figure 56

Absorption chillers typically include the following mechanical components: pump(s) to circulate refrigerant and absorbent solution, a purge to remove noncondensables from the chiller, a burner (if directly-fired), and a steam or hot water control valve (if indirectly-fired).

Chiller manufacturers use different types of pumps. Some use a single pump, while others use individual pumps. Some use hermetic pumps that are cooled and lubricated by the pumped solution, and others use pumps with open motors that require an external shaft seal. The pumps should be disassembled and inspected at routine intervals. Be sure to consult the manufacturer for specific recommendations.

With the advent of microprocessor-based controls, the control panel and auxiliary controllers require no recalibration or maintenance. Remotely-mounted electronic sensors send information to the chiller controller, which can be connected to a building automation system to communicate information and allow system-level optimization. These systems can notify the operator with an alarm or diagnostic message when a problem occurs.

As for any mechanical equipment, a daily visual inspection of the chiller is recommended to look for condensation, loosened electrical or control wiring, or signs of corrosion. Special attention should be given to safety controls and electrical components.

notes

Purge System

- **Weekly maintenance**
  - Check level of liquid refrigerant in purge condensing unit
  - Check vacuum pump oil
- **Semiannual maintenance**
  - Inspect purge condensing coil and clean as necessary
  - Change vacuum pump oil as needed

Figure 57

Most purges are fully automatic and generally require less maintenance than previous-generation manually operated purges. Purge-related maintenance procedures are simple.

- **Weekly:** With the purge unit operating, check the purge tank condensing activity by observing the liquid refrigerant level in the sump sight glass and checking the vacuum pump oil.
- **Semiannually:** Inspect the air-cooled condensing-unit coil and clean as needed. A fouled coil will reduce purge efficiency and capacity. Change the vacuum pump oil as needed.

As mentioned in Period Three, the purge can be used to indicate an air leak or depletion of the corrosion inhibitor. Leaks can be detected early by comparing pump-out activity over the last 24 hours to the 30-day average. The hermetic integrity of the absorption chiller is critical to its operation. Any leaks should be addressed immediately.

notes

Direct-Fired Burner

- **Daily maintenance**
  - Verify proper operation
- **Seasonal maintenance**
  - Inspect burner firing rate, blower, linkage, and safety controls
  - Test run with alternate fuel, if dual-fuel burner

Figure 58

The burner is the heart of a direct-fired absorption chiller. Correct operation is, therefore, necessary for optimum chiller performance. Daily checks should be made in accordance with the manufacturer's recommendations. Each cooling season, the burner's firing rate, blower, linkage, and safety controls should be checked to ensure proper operation. If a dual-fuel burner is being used, it should be periodically test run with the alternate fuel to ensure reliable operation.

Manufacturers of direct-fired absorption chillers provide detailed burner maintenance checklists, generally with maintenance requirements at 3-, 6-, and 12-month intervals. To ensure efficiency and increase longevity of both the burner and the chiller, consult manufacturers' maintenance manuals and follow their instructions.

With indirect-fired absorption chillers, periodic inspection of the energy valve is recommended to check for leaks. Again, consult manufacturers' maintenance manuals for specific recommendations.

notes

Heat Transfer Surfaces

- **Recommended maintenance**
  - Use a qualified water treatment specialist
  - Clean absorber and condenser tubes as needed
  - Clean waterside strainers
  - Test tubes every 3 years

Figure 59

The use of better heat-transfer materials will reduce future maintenance costs. The high-temperature generator, for example, contains high-temperature lithium bromide solution that, when exposed to air and other noncondensables, is more corrosive than in other sections of the chiller. Better materials in the high-temperature generator will improve reliability and require less maintenance. When selecting an absorption chiller, both installation and maintenance costs must be considered when comparing different designs.

To ensure optimum heat transfer performance, the heat transfer surfaces must be kept free of scale and sludge. Even a thin deposit of scale can substantially reduce heat transfer capacity. Engage the services of a qualified water treatment specialist to determine the level of water treatment required to remove contaminants from the cooling water.

Scale deposits are best removed by chemical means. During this process, the absorber and condenser are commonly isolated from the rest of the cooling-tower-water circuit by valves, while a pump circulates cleaning solution through the tubes.

Sludge is removed mechanically. This typically involves removing the water boxes from the absorber and condenser, and loosening the deposits with a stiff-bristled brush. The loosened material is then flushed from the tubes with clear water. As part of this procedure, the strainers in both the chilled-water and cooling-water circuits should be cleaned every year.

Every three years (more frequently in process or critical applications), a qualified service organization should perform nondestructive inspections of the tubes inside the generator(s), condenser, evaporator, absorber, and heat exchanger(s). The eddy-current tube test is a common method.

notes

Corrosion Inhibitors

- **Absorbent solution analysis**
  - Conduct annually or semiannually
  - Verifies corrosion inhibitor levels
  - Verifies performance additive levels
- **Refrigerant analysis**
  - Conduct annually

Figure 60

An absorption chiller requires a very deep vacuum to operate efficiently. The introduction of air and other noncondensables into the chiller will adversely affect the chiller's performance. In a lithium bromide absorption chiller, where the absorbent is a salt, corrosion is a potential problem that must be avoided. It may not be possible to completely prevent corrosion inside the chiller, although it can be reduced or controlled by the addition of a chemical called a **corrosion inhibitor**.

Corrosion inhibitors are primarily intended to protect the steel components of the chiller from the corrosive action of the lithium bromide-and-water mixture. The inhibitor is added to the lithium bromide solution to promote the formation of a thin protective layer of oxide quickly and uniformly over the steel components inside the chiller. This coating is more impervious to the reaction with water, resulting in longer life for the chiller. Corrosion inhibitors also reduce the production of noncondensable gas that is generated during the corrosion process. The corrosion inhibitor, however, does not directly protect the copper components from corrosion. Corrosion protection for the copper heat transfer components primarily depends on the materials selected to assure maximum design life.

Additionally, most lithium bromide absorption chillers use a chemical **performance additive** to achieve and maintain design performance. This additive considerably enhances the rate at which refrigerant vapor is absorbed by the lithium bromide solution.

period four
Maintenance Considerations

notes

If air leaks into the chiller, the corrosion inhibitor is depleted as it reacts with the air and produces hydrogen. To maintain chiller efficiency and ensure continued corrosion protection, the lithium bromide solution must be analyzed periodically to determine if corrosion inhibitor and performance additive levels are within acceptable limits. This is the most important periodic maintenance requirement! A laboratory test is required to determine these levels. Suggested intervals for testing are once per year for comfort-cooling applications and twice per year for chillers in continuous or critical service. Analysis of the refrigerant is also recommended. Consult the chiller manufacturer for specific corrosion inhibitor and performance additive recommendations.

period five

Application Considerations

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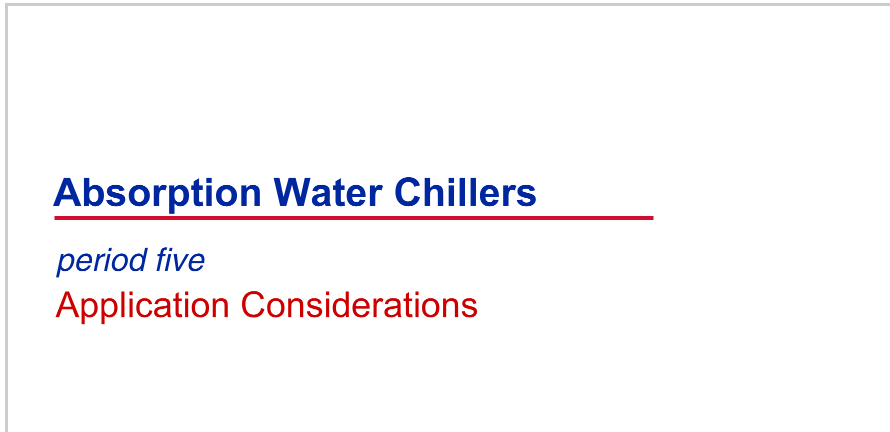

Figure 61

Several considerations must be addressed when applying absorption water chillers, including:

- Cooling-water temperature limitations
- Combination chiller plants
- Special considerations for direct-fired chillers
- Equipment rating standards

While not all-inclusive, this list does represent some of the key issues.

notes

Cooling-Water Temperature Limitations

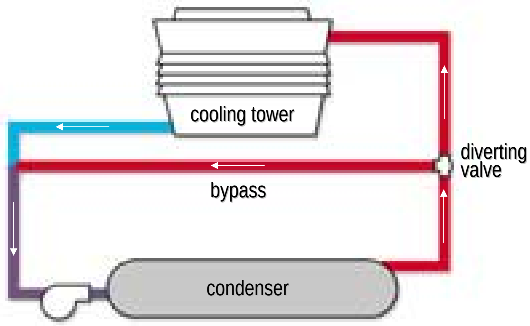

Figure 62

Cooling-Water Temperature Limitations

The temperature of the cooling water significantly impacts the operation of an absorption chiller. As the temperature of the entering-cooling-water decreases, chiller capacity increases.

Some absorption chiller designs can experience operational problems if the cooling-water temperature changes too rapidly or becomes too low. If the temperature of the cooling water changes too rapidly, there is potential for the absorbent solution to carry over from the generator into the condenser. This increases the risk of corrosion in the condenser and evaporator sections of the chiller, and reduces the cooling capacity of the chiller. Additionally, low cooling-water temperatures increase the risk of crystallization. When applying these chillers, a cooling tower bypass is typically recommended for stable control of the cooling-water temperature.

In some new chiller and control designs, variable-speed drives are used to vary the flow of solution through the chiller, allowing the chiller to maintain tight control in situations where the cooling-water temperature may be highly variable. In many cases, this means that a cooling tower bypass may not be required, although this should be verified by the system designer. In applications that require tight control of the leaving-chilled-water temperature, however, it is still generally recommended to design the system to minimize the rate at which the cooling-water temperature varies.

In all cases, the chiller manufacturer should be consulted for specific cooling-water temperature limitations and control requirements.

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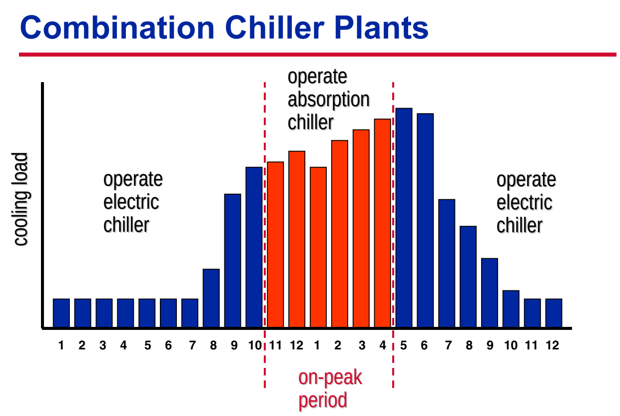

Figure 63

Combination Chiller Plants

Absorption chillers possess two operating characteristics that can noticeably improve overall system efficiency and reduce system energy costs.

First, absorption chillers use fossil fuels rather than electricity. Operating absorption chillers at times when on-peak electric energy and/or demand costs are high reduces total system utility costs. In such installations, the absorption chiller can operate during on-peak periods to avoid the high cost of electricity. The electric chiller can run during off-peak periods to take advantage of the lower cost of electricity.

Combination gas-and-electric plants can also exploit the heating capability of direct-fired absorption chillers. Both electric and absorption chillers can be used to provide summer cooling. If the electric chiller is large enough to satisfy the entire winter cooling load, the direct-fired absorption chiller can be switched to heating operation to either satisfy the entire winter heating load or supplement the primary heating equipment. In such applications, selection of the direct-fired absorption chiller should be made to allow downsizing, or perhaps even elimination of, the primary heating equipment.

notes

Combination Chiller Plants

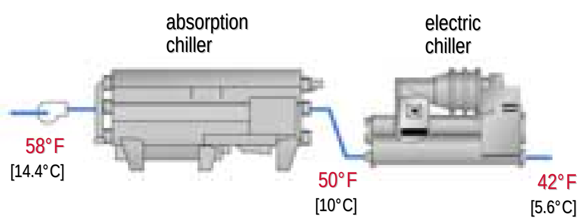

Figure 64

The second beneficial operating characteristic is that an absorption chiller works more efficiently and produces more cooling with increased leaving-chilled-water temperatures.

Applications with two chillers can be either piped in series or in parallel. Though there are advantages associated with each arrangement, the series configuration allows a noticeable increase in the overall system efficiency of a combination gas-and-electric chiller plant. The series arrangement allows the upstream chiller to cool the water part of the way and uses the downstream chiller to cool the water the rest of the way to the setpoint. Placing the absorption chiller in the upstream position allows it to provide a warmer leaving-chilled-water temperature, 50°F [10°C] in this example. This not only improves the absorption chiller's efficiency and capacity, but also reduces the cooling load and energy consumption of the electric chiller.

The series arrangement also has the capability to preferentially load the gas-burning chiller, allowing the system to maximize the use of lower-cost fuel during periods of high electrical energy cost. Piping two chillers in series also means that the entire system-water flow must pass through both chillers. Exercise care when selecting the chillers to avoid exceeding their maximum flow rates. Notice that the example series arrangement shown here also takes advantage of a 16°F [8.9°C] temperature differential across the chillers. This increased temperature differential allows the water flow rate to be reduced and results in lower pumping costs.

Overall, the key to successful implementation of a combination gas-and-electric chiller plant is an intelligent building automation system that optimizes chiller plant operation relative to electrical and gas utility rate structures.

notes

Direct-Fired Chiller Considerations

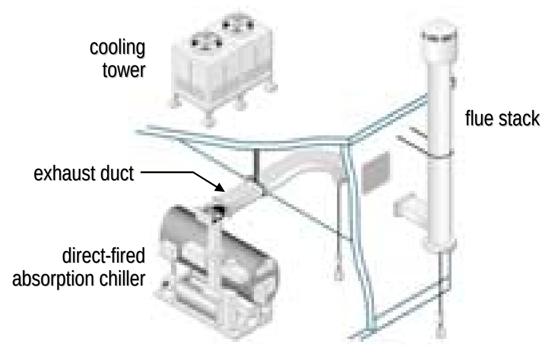

Figure 65

Special Considerations for Direct-Fired Chillers

The combustion process that occurs in the burner is key to the operation of a direct-fired absorption chiller. It also introduces several additional considerations when applying this type of chiller.

- **Combustion air requirements:** Combustion equipment is designed and operated to ensure complete combustion. Incomplete combustion uses fuel inefficiently, can be hazardous because of carbon monoxide production, and contributes to air pollution. The quantity of air to provide for a particular direct-fired absorption chiller installation is determined by such factors as expected variations in fuel and air supplies, system application, burner design, and control requirements.
- **Venting of exhaust:** A flue exhaust-gas duct and stack must be installed to effectively vent the products of combustion out of the building. This duct and stack must be designed and installed in compliance with municipal, state, and federal regulations. Also, be careful not to locate the stack too close to the cooling tower.
- **Gas train:** The main gas control train regulates the fuel flow to the burner manifold and provides safe operation. The gas train is selected based upon the pressure of the gas main and local code requirements.
- **NO_x emissions:** Nitrogen oxides (NO_x) are the combustion emissions containing nitrogen and oxygen in direct-fired absorption chiller applications. Due to environmental concerns, some local building codes require low NO_x emissions. Manufacturers have developed low-NO_x burners that use various methods for reducing emissions. One cost-effective method of achieving low emissions in commercial installations, flue-gas recirculation, recycles flue gases to lessen NO_x formation by reducing the flame temperature and the amount of oxygen available for combustion.

notes

ASHRAE Standard 15–1994

- **Open-flame devices**
  - Combustion air ducted from outside the machinery room
  - Refrigerant vapor detector to shut down combustion process in the event of a refrigerant leak

Figure 66

In general, ASHRAE Standard 15-1994, "Safety Code for Mechanical Refrigeration," does not apply to absorption water chillers due to Section 2.3, which states:

> *This code does not apply where water is the primary refrigerant.*

Section 8.13.6 of the Standard, however, does affect direct-fired absorption chillers. It states:

> *No open flames that use combustion air from the machinery room shall be installed where any refrigerant is used ... Combustion equipment shall not be installed in the same machinery room with refrigerant-containing equipment except under one of the following conditions:*
>
> *(a) Combustion air is ducted from outside the machinery room and sealed in such a manner as to prevent any refrigerant leakage from entering the combustion chamber, or*
>
> *(b) A refrigerant vapor detector is employed to automatically shut down the combustion process in the event of refrigerant leakage.*

When halocarbon refrigerants (such as HCFC-123, HCFC-22, HFC-134a, etc.) are present during a combustion process, they can break down into products that are both harmful to humans and corrosive to machinery. The intent of Standard 15 is to avoid both of these hazards by preventing refrigerant exposure to any combustion process. Thus, the use of an open-flame device, such as a boiler or the burner of a direct-fired absorption chiller, in a machinery room is strictly prohibited by this section unless one of the exceptions is employed.

Exception (a) allows combustion air to be ducted to the open-flame device from outside the machinery room in order to prevent air (and refrigerants) present in the machinery room from entering the flame. Alternatively, exception (b) allows

notes

a refrigerant vapor detector to monitor refrigerant levels in the machinery room. When the detector measures refrigerant levels above those allowable, a building automation system is used to automatically shut down the combustion process. Due to the lower cost, many building owners employ exception (b) in machinery rooms that have direct-fired absorption chillers or boilers.

Equipment Rating Standards

- **Purpose**
  - Establish definitions, testing, and rating requirements
- **Scope**
  - Single- and double-effect absorption chillers
  - Indirect- and direct-fired absorption chillers
  - Water-and-lithium bromide solution

Figure 67

Equipment Rating Standards

The Air Conditioning & Refrigeration Institute (ARI) establishes rating standards for packaged HVAC equipment. The overall objective of ARI Standard 560 is to promote consistent rating of many types and sizes of absorption water chillers. It covers single-effect chillers operating on steam or a hot fluid, double-effect chillers operating on steam or a hot fluid, and direct-fired double-effect chillers operating on natural gas, oil, or liquid petroleum (LP). It pertains to chillers using water as the refrigerant and lithium bromide as the absorbent.

The standard rating conditions used for ARI rating represent typical design temperatures and flow rates for which water-cooled systems are designed. They are not suggestions for good design practice for a given system—they simply define a common rating point to aid comparisons. Trends toward improved *system* energy efficiency have changed some of the actual conditions for specific applications.

Impurities in the chilled- and cooling-water systems eventually deposit on evaporator, absorber, and condenser tube surfaces, impeding heat transfer. Catalogued performance data includes a fouling factor that accounts for this effect to more closely predict actual chiller performance.

Remember that the ARI rating is a standardized representation. Many chillers do not run at standard rating conditions. Performing a comprehensive energy analysis is still the best method of comparing the system operating cost difference between two chillers.

period six
Review

notes

Absorption Water Chillers

period six
Review

Figure 68

We will now review the main concepts that were covered in this clinic on absorption water chillers.

Review—Period One

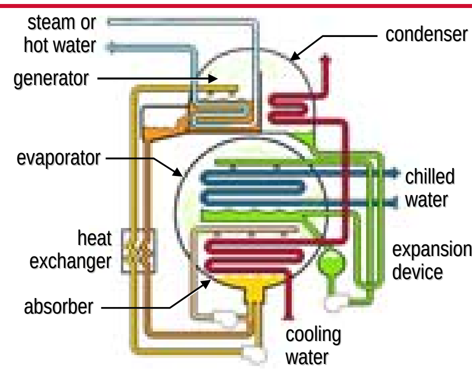

Figure 69

Period One presented the basic single-effect, absorption refrigeration cycle. In the **generator**, dilute solution absorbs heat from the steam or hot water flowing through the tubes, causing the refrigerant to boil and separate from the absorbent solution. As the refrigerant boils away, the absorbent solution becomes concentrated and returns to the absorber. The resulting refrigerant vapor migrates to the cooler **condenser**, where heat transfers from the hot refrigerant vapor to the cooling water inside the tubes, causing the refrigerant to condense on the tube surfaces. The resulting condensed liquid refrigerant flows through an **expansion device**, causing a pressure drop that reduces the refrigerant pressure to that of the evaporator. This pressure reduction causes a small portion of the liquid refrigerant to boil off, cooling the remaining refrigerant to the desired evaporator temperature. The cooled mixture of liquid

notes

and vapor refrigerant then flows into the **evaporator** pan, from which the **evaporator spray pump** continuously pumps the liquid refrigerant to be sprayed over the tubes. As heat transfers from the chilled water flowing through the tubes to the cooler refrigerant, the refrigerant boils (vaporizes) and the resulting refrigerant vapor is drawn into the absorber.

Inside the **absorber**, the refrigerant vapor is absorbed by the lithium bromide solution, releasing heat to the cooling water which is circulated through the tubes. Absorption of the refrigerant vapor creates a low pressure area within the absorber, inducing a continuous flow of refrigerant from the evaporator to the absorber. The **absorber spray pump** mixes concentrated absorbent solution (returning from the generator) with dilute solution (from inside the absorber) and delivers this intermediate solution to the absorber sprays. The lithium bromide solution becomes diluted as it absorbs the refrigerant. To complete the cycle, the **generator pump** continuously returns the dilute absorbent solution to the generator to be reconcentrated. This cool dilute solution passes through a **heat exchanger** to be preheated by the hot concentrated solution returning from the generator.

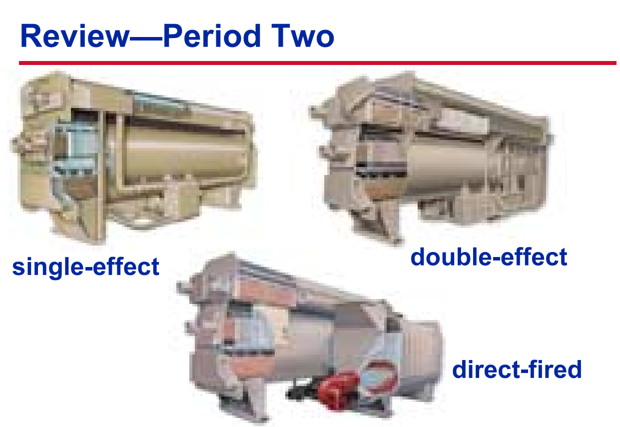

Figure 70

Period Two discussed the various types of absorption water chillers, including the single-effect, double-effect, and direct-fired chillers.

The double-effect absorption chiller includes the same basic components as the single-effect chiller, and also includes an additional generator, heat exchanger, and pump. The high-temperature generator can use steam or a hot liquid such as water as the energy source (indirect-fired) or the combustion of a fossil fuel such as natural gas or oil as the energy source (direct-fired).

This period also introduced the use of the direct-fired absorption chiller/heater to provide both cooling and heating.

period six
Review

notes

Review—Period Three

- **Part-load capacity control**
  - Vary solution flow to generator
  - Vary heat input to generator
- **Crystallization prevention**
  - High-quality construction
  - Microelectronic controls
  - Automatic purge systems
  - De-crystallization devices
- **Purge system**

Figure 71

Period Three explained the part-load operation of the absorption chiller. It described the use of energy valves, burner controls, throttling and bypass valves, and adjustable-frequency drives as methods for controlling the capacity on the chiller. Valves and AFDs are used to vary the flow rate of solution to the generator. Modulating energy valves and burner controls are used to vary the heat input to the generator.

It also introduced the concept of crystallization, which occurs when the absorbent solution becomes saturated and the salt begins to leave the solution as a solid. Causes of crystallization include: air and other noncondensable gases leaking into the chiller, cooling water that is too cold or that fluctuates in temperature too rapidly, and an electric power failure. In most modern absorption chiller designs, high-quality construction, smart microelectronic controls, and automatic purge systems are extremely effective in avoiding crystallization. Additionally, most absorption water chillers include devices that allow the chiller to recover in the event that crystallization does occur.

The operation of the purge system as a means of removing air and other noncondensables from inside the chiller was also presented.

notes

Review—Period Four

- Maintenance considerations
  - Operating log
  - Mechanical components
  - Heat transfer surfaces
  - Absorbent solution analysis (corrosion inhibitor and performance additive levels)

Figure 72

Period Four described general maintenance requirements for absorption water chillers, including:

- Recommended data for a daily log
- Recommended maintenance for mechanical components, such as the solution and refrigerant pumps, purge, and burner
- Recommended maintenance for heat-transfer surfaces
- Required analysis of the absorbent solution to ensure acceptable levels of the corrosion inhibitors and performance additives

Review—Period Five

- Application considerations
  - Cooling-water temperature limitations
  - Combination gas-and-electric chiller plants
  - Special considerations for direct-fired chillers
  - Equipment rating standards

Figure 73

Period Five presented several considerations for applying absorption water chillers. These included cooling-water temperature limitations, the advantages of using combination gas-and-electric chiller plants, special considerations when using direct-fired chillers, and equipment rating standards.

period six
Review

notes

An American Standard Company

Figure 74

For more information, refer to the following references:

- Trane product catalogs for absorption water chiller products (Trane literature order numbers ABS-DS-1, ABS-DS-4, ABS-DS-6, and ABS-PRC001-EN)
- *Absorption Chiller System Design* Applications Engineering Manual (Trane literature order number SYS-AM-13)
- Trane *Air Conditioning Manual*
- *Equilibrium Chart for Aqueous Lithium Bromide Solutions* laminated chart, I-P units (Trane literature order number 1-43.198)
- *ASHRAE Handbook – Fundamentals*
- *ASHRAE Handbook – Refrigeration*

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For more information on additional educational materials available from Trane, contact your local Trane office (request a copy of the Educational Materials catalog — Trane order number EM-ADV1) or visit our online bookstore at www.trane.com/bookstore/.

Quiz

Questions for Period 1

1 What are the names of the two working fluids used within the absorption cycle?

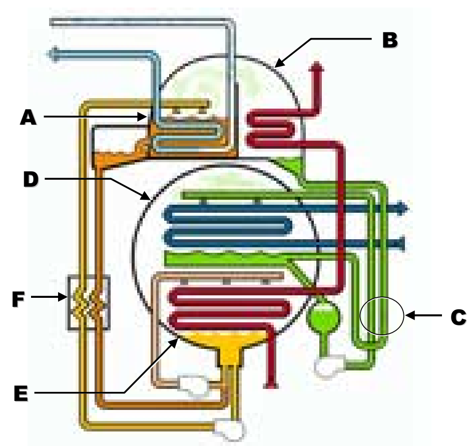

Figure 75

2 Identify the components of the absorption refrigeration cycle labeled in Figure 75.

3 What are the two major components on the high-pressure side of the absorption refrigeration cycle? What are the two major components on the low-pressure side of the cycle?

4 Does the absorption cycle operate at pressures above or below atmospheric pressure?

5 Which of the following components do not contain absorbent solution? (generator, condenser, evaporator, absorber, heat exchanger)

6 What is the purpose of the heat exchanger in the absorption refrigeration cycle?

Questions for Period 2

7 What additional components are included on a double-effect absorption chiller versus a single-effect chiller?

8 Which type of absorption water chiller is capable of providing simultaneous cooling and heating?

Quiz

Questions for Period 3

9 Does an increase in solution concentration, assuming a constant solution temperature, result in an increase or decrease in vapor pressure?

10 What is crystallization?

11 What are the most common causes of crystallization in an absorption chiller and how can these conditions be avoided?

Questions for Period 4

12 What is the purpose of analyzing the lithium bromide solution?

Questions for Period 5

13 True or False: All absorption water chillers require the use of a cooling tower bypass for stable control of the cooling-water temperature.

14 List two special considerations discussed in this clinic for applying direct-fired absorption water chillers.

Answers

1 Refrigerant (distilled water) and absorbent (lithium bromide)

2 **A** generator, **B** condenser, **C** expansion device, **D** evaporator, **E** absorber, **F** heat exchanger

3 Generator and condenser; evaporator and absorber

4 Below atmospheric pressure

5 Condenser and evaporator

6 To preheat the dilute solution returning to the generator, which reduces the heat energy required to boil the refrigerant, and precool the concentrated solution returning to the absorber, which reduces the flow rate of cooling water required to absorb heat in the absorber.

7 High-temperature generator, high-temperature heat exchanger, and possibly an additional pump (depending on the type of flow cycle used)

8 Direct-fired absorption chiller (with an auxiliary heating bundle)

9 Decrease in vapor pressure

10 The process of lithium bromide leaving the solution as a solid when the absorbent solution is cooled below its saturation temperature.

11 Air leaking into the chiller, avoided by quality construction and automatic purging. Cooling water that is too cold or that fluctuates in temperature too rapidly, avoided by using improved microelectronic controls or a cooling tower bypass. Electric power failure, avoided by gravity-fed dilution cycles.

12 To determine if corrosion inhibitor and performance additive levels are within acceptable limits. Air leaking into the chiller can deplete the corrosion inhibitor.

13 False. Many new chiller and control designs are able to maintain control of the cycle, even in situations where the cooling-water temperature may be highly variable.

14 Quantity of combustion air required, venting of combustion exhaust, sizing of the main gas train, requirements for low NO_x emissions, and compliance with ASHRAE Standard 15.

Glossary

absorbent A substance used to absorb refrigerant and transport it from the low-pressure to the high-pressure side of the absorption refrigeration cycle. In absorption water chillers, the absorbent is commonly lithium bromide.

absorber A component of the absorption refrigeration system where refrigerant vapor is absorbed by the absorbent solution and rejects heat to cooling water.

adjustable-frequency drive (AFD) A device used to control the capacity of a pump by varying the speed of the pump motor.

ARI Air Conditioning & Refrigeration Institute.

ARI Standard 560 A publication, titled *"Absorption Water Chilling and Water Heating Packages,"* used to promote consistent rating methods for many types and sizes of absorption water chillers, using water as the refrigerant and lithium bromide as the absorbent. It covers single-effect chillers operating on steam or a hot fluid; indirect-fired double-effect chillers operating on steam or a hot fluid; and direct-fired double-effect chillers operating on natural gas, oil, or liquid petroleum (LP).

ASHRAE American Society of Heating, Refrigerating and Air-Conditioning Engineers.

ASHRAE Standard 15 A publication, titled *"Safety Code for Mechanical Refrigeration,"* that specifies safe design, construction, installation, and operation of refrigerating systems.

auxiliary heating bundle A separate heat exchanger added to a direct-fired absorption chiller to allow it to provide simultaneous cooling and heating.

chilled water The cold water produced by the chiller (flowing through the tubes in the evaporator) and pumped to the air-handler coils throughout the building.

chilled-water system Uses water as the cooling media. The refrigerant inside the evaporator absorbs heat from the water and this water is pumped to coils in order to absorb heat from the air used for space conditioning.

coefficient of performance (COP) A dimensionless ratio used to express the efficiency of a refrigeration machine. For an absorption water chiller, it is defined as the ratio of evaporator cooling capacity divided by the heat energy required by the generator, excluding the electrical energy needed to operate the pumps, purge, and controls. A higher COP designates a higher efficiency.

compressor A mechanical device used in the vapor-compression refrigeration cycle to increase the pressure and temperature of the refrigerant vapor.

concentrated absorbent solution A mixture of refrigerant and absorbent that has a relatively low refrigerant content and high absorbent content.

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condenser A component of the absorption refrigeration system in which refrigerant vapor is converted to liquid as it rejects heat to cooling water.

cooling water Water obtained from a source (cooling tower, river, pond) to which heat is rejected. This water flows through tubes in the absorber and the condenser.

corrosion inhibitor Chemical added to the absorbent solution to protect the steel components of the chiller from the corrosive action of the water and lithium bromide solution.

crystallization The process of the absorbent leaving the solution as a solid, when the solution is cooled below its saturation temperature.

dilute absorbent solution A mixture of refrigerant and absorbent that has a relatively high refrigerant content and low absorbent content.

direct-fired A type of absorption chiller that uses the combustion of a fossil fuel (such as natural gas or oil) directly to provide heat to the high-temperature generator.

double-effect A type of absorption chiller that uses two generators, a high-temperature generator and a low-temperature generator.

equilibrium chart A graphical representation of the properties of lithium bromide solutions. Vapor pressure is plotted on the vertical axis, solution temperature on the horizontal axis, and concentration on the diagonal lines.

evaporator A component of the absorption refrigeration system where cool liquid refrigerant absorbs heat from water (from the building system), causing the refrigerant to boil.

expansion device A component of the absorption refrigeration system used to reduce the pressure and temperature of the refrigerant to desired evaporator conditions.

flash The process of liquid refrigerant being vaporized by a sudden reduction of pressure.

generator A component of the absorption refrigeration system in which refrigerant vapor boils and is separated from the absorbent solution as it absorbs heat from the primary heat source.

indirect-fired A type of absorption chiller that uses steam or a hot fluid (such as water) from an external source to provide heat to the generator.

intermediate absorbent solution A mixture of refrigerant and absorbent that is a combination of dilute and concentrated solutions.

performance additive Chemical added to the absorbent solution to enhance the rate at which refrigerant vapor is absorbed by the lithium bromide solution, improving the performance of the cycle.

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purge A device used to remove air and other noncondensable gases that may leak into the low-pressure absorption chiller.

refrigerant A substance used to absorb and transport heat for the purpose of cooling. In a large absorption water chiller, the refrigerant is distilled water.

saturation temperature The temperature, for a given concentration, at which the solution contains the most salt that it can hold. If the temperature drops any further, the salt begins to leave the solution in a solid form (crystallize).

single-effect A type of absorption chiller that uses a single generator.

throttling pipe A type of expansion device used in absorption water chillers. It is a section of pipe with an orifice inside.

variable-speed drive *See* adjustable-frequency drive.

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Literature Order Number	TRG-TRC011-EN
File Number	E/AV-FND-TRG-TRC011-0400-EN
Supersedes	2803-11-677
Stocking Location	La Crosse